PB84-213321

Nationwide Urban Runoff Program
Upper Mystic Lake Watershed
Urban Runoff Project: Summary

Massachusetts Dept. of Environmental Quality
Engineering, Boston

Prepared for

Environmental Protection Agency, Washington, DC

Oct 82

U.S. Department of Commerce
National Technical Information Service
NTIS

PB84-213321

Commonwealth of Massachussetts
Department of Environmental Quality Engineering
Office of Planning and Program Management

UPPER MYSTIC LAKE WATERSHED URBAN RUNOFF PROJECT

SUMMARY

OCTOBER 1982

Edward J. King, Governor
John A. Bewick, Secretary, E.O.E.A.
Anthony D. Cortese, Sc.D., Commissioner, D.E.Q.E.

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No. PB83 213321
4. Title and Subtitle: Nationwide Urban Runoff Program, Upper Mystic Lake Watershed, Urban Runoff Project, SUMMARY.			5. Report Date: October, 1982 6.
7. Author(s): Nancy Apple Fratoni, Nancy Cranker, and Susan Kaufman			8. Performing Organization Rept. No.
9. Performing Organization Name and Address: Mass. Dept. of Environmental Quality Engineering Office of Planning and Program Management 100 Cambridge Street Boston, MA 02202			10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G) P 001114016
12. Sponsoring Organization Name and Address: EPA, Office of Water Program Operations Water Planning Division 401 M Street, SW Washington, D C 20460			13. Type of Report & Period Covered: Final Jun 76 - Oct 82 14.

15. Supplementary Notes: This volume comprises 1 of 4 volumes that make up the entire report.

16. Abstract (Limit: 200 words):

The major objectives of this project were to:

1. Identify the quality and quantity characteristics of urban runoff in the Upper Mystic Lake Watershed;
2. Assess the impact of urban runoff on the Aberjona River and Upper Mystic Lake; and
3. Recommend controls to acheive quality goals in the Upper Mystic Lake.

With these objectives identified, the study was designed as a more comprehensive assessment of water quality conditions and as such, considered the various other sources of pollution and their relative contributions to the overall problem.

17. Document Analysis a. Descriptors

Hydrology, Urban development, Watersheds, Water pollution, Water resources, Sedimentation, Storms, Regional planning, Urban planning, Civil Engineering

b. Identifiers/Open-Ended Terms

Runoff, Streamflow, Stream pollution, Rainfall, Snowmelt, Soil Erosion, Water Quality, Sediments, Sediment Transport, Suspended Solids, Storm Drains, Urbanization, Land use

c. COSATI Field/Group

18. Availability Statement: No restriction on distribution. Available from National Technical Information Service, Springfield, VA 22161	19. Security Class (This Report): UNCLASSIFIED	21. No. of Pages: 71
	20. Security Class (This Page): UNCLASSIFIED	22. Price

(See ANSI-Z39.18) See Instructions on Reverse

OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

UPPER MYSTIC LAKE WATERSHED

URBAN RUNOFF PROJECT

SUMMARY REPORT

Prepared by

Nancy Apple Fratoni, Project Manager
Nancy Cranker, Water Resource Planner
Susan Kaufman, Limnologist

Massachusetts Department of Environmental Quality Engineering
Office of Planning and Program Management

October 1982

This report was prepared with the assistance of the U.S. Environmental Protection Agency through a grant to the Massachusetts Department of Environmental Quality Engineering under the Nationwide Urban Runoff Program.

TABLE OF CONTENTS

1. Introduction 1

2. Description of the Watershed 6

3. Water Quality Goals 17

4. Water Quality Problems 26

5. Pollution Sources and Controls 43

6. Summary 54

Bibliography

Glossary

LIST OF TABLES

1. Urban Runoff Pollutants and Sources 2

2. Long-term Precipitation Characteristics 10

3. Spatial Rainfall Variability 11

4. Upper Mystic Lake Physical Data 13

5. Community Population Changes in the Upper Mystic Lake Watershed 16

6. Water Quality Classification for In-land Waters 18

7. Upper Mystic Lake Watershed Water Quality Classification 19

8. Uses of Major Water Bodies - Survey Results 20

9. Desired Future Uses of Major Water Bodies - Survey Results 21

10. Factors Affecting Uses of Major Surface Water Bodies - Survey Results 25

11. Comparison of Oligotrophic and Eutrophic Lakes 28

12. Summary of Upper Mystic Lake Pollutant Sources - Percentage of Calculated Load 30

13. Comparison of Stormwater Quality 44

14. Point Source Discharge Permits 47

15. Areas with Surcharging Sewer Problems in Winchester 49

LIST OF FIGURES

1. Community Boundaries 7
2. Major Transportation Network 8
3. Bathymetric Controus 12
4. Publicly Owned Lands Adjacent to Major Waters 22
5. Urban Runoff Project Monitoring Locations 32
6. Urban Runoff Project Monitoring Locations 33
7. Typical Temperature and Dissolved Oxygen Profile 35
8. Aquatic Vegetation 40
9. Upper Mystic Lake Fish Population Distribution 42

1. INTRODUCTION

WHAT IS URBAN RUNOFF?

Urban runoff is the water which comes off lawns, rooftops, streets and other paved areas during and after a rainstorm or during snow melt. As the runoff (or stormwater) travels, it picks up contaminants, including nutrients, sediments, metals, litter and organic and bacterial wastes, along its path. The streets may seem cleaner after a rainstorm, but in fact, the pollutants have merely been transferred to local catch basins and receiving waters. Additionally, greater volumes of water run off urban areas since a larger portion of the land is covered by structures and paved surfaces.

The types of runoff contaminants which end up in stormwater vary greatly, and determining their origin is often difficult. Studies have, however, linked some runoff pollutants with their sources. Table 1 lists common runoff pollutants and the sources from which they usually originate. Although these contaminants are regularly found in runoff, their quantity varies geographically due to factors such as land use, climate, and geological differences. Although each watershed is unique, comparisons can be made between similar areas.

WHY ARE WE CONCERNED?

Water quality conditions throughout the Upper Mystic Lake Watershed are generally below the state standards assigned by the Department of Environmental Quality Engineering, and fall short of the quality desired by local residents, particularly for recreation.

The value of the water resources in the Watershed has been recognized at the local, regional, state and federal levels as reflected by funds spent over the past 10 years for the study and control of pollution sources and interest expressed throughout this project. While several studies have identified urban runoff as a major pollution problem, the specific nature of

Table 1: URBAN RUNOFF POLLUTANTS AND SOURCES

POLLUTANT	SOURCES
Aluminum	soils
Arsenic	herbicides, soils
Cadmium	soils, tires
Chromium	atmospheric deposition, engine plating, soils
Copper	brake linings, engine plating, pesticides, soils
Iron	rust, soils
Lead	leaded fuels, motor oils, soils, tires
Manganese	fertilizers, motor oils, soils
Nickel	engine plating, soils
Nitrogen Compounds	atmospheric deposition, fertilizers, plant materials, tires
Oil and Grease	hydraulic fluids, motor oils
Oxygen Demanding Compounds (measured as BOD)	organic matter
Phosphorus Compounds	atmospheric deposition, fertilizers, plant materials
Solids	atmospheric deposition, erosion, road abrasion, road sanding
Zinc	motor oils, soils, tires

urban runoff in the Watershed and its impact on water quality conditions had never been documented. This information is essential if water quality goals are to be attained and potential recreational opportunities fully realized.

UPPER MYSTIC LAKE WATERSHED URBAN RUNOFF PROJECT

The Upper Mystic Lake Watershed Urban Runoff Project is one of 28 prototype studies conducted across the country as part of the U.S. Environmental Protection Agency's (EPA) Nationwide Urban Runoff Program (NURP). This program was developed in response to a request from Congress for information on the magnitude of the stormwater problem nationwide and the advisability of making stormwater control facilities eligible for funding under EPA's Construction Grants Program. When the Clean Water Act was amended in 1977, Congress removed this eligibility on the grounds that there was not adequate information showing either that stormwater created water quality problems, impaired beneficial uses, or that stormwater could be effectively controlled. Thus, EPA developed the NURP program whose objectives are to determine the nature, cause and severity of urban runoff problems, and opportunities for controlling these problems. The likelihood of future federal funding for stormwater control seems unlikely at this point, making community concern extremely important.

The availability of funds under the NURP program provided an excellent opportunity to gather the information required on urban runoff as a source of pollution in the Upper Mystic Lake Watershed. The Mystic Project competed favorably with other proposals because of the water quality work done in the past, and the local, regional and state commitment to improving water quality conditions.

The major objectives of the Mystic Project were:

- To identify the quality and quantity characteristics of urban runoff in the Upper Mystic Lake Watershed;
- To assess the impact of urban runoff on the Aberjona River and Upper Mystic Lake; and
- To recommend controls to achieve quality goals in the Upper Mystic Lake.

While these objectives were specific to urban runoff, the study was designed as a more comprehensive assessment of water quality conditions and, as such, considered the various other sources of pollution in the Watershed.

STUDY METHODS

The specifics of the data collection and analysis components of this project are detailed in the Main Report, as discussed below. An extensive data collection program was conducted between February and November of 1981 by DEQE, our consultants, Environmental Design Planning, Inc., the Metropolitan District Commission, and volunteers organized by the Mystic River

Watershed Association. Specific components of the program include:

- Water quality sampling along the Aberjona River and in the Upper Mystic Lake during dry weather and after storms;
- Water quality sampling at two stormwater sites in Reading, and in several locations in Winchester's stormwater collection system;
- Rainfall measurement at various sites throughout the Watershed;
- Depth sounding to determine lake depth;
- Circulation studies to determine flow patterns in the Lake;
- Surveys of aquatic vegetation, fish populations, and bottom dwelling organisms and analysis of lake sediment quality.

As part of data analysis, project consultants Camp Dresser and McKee, Inc. developed several mathematical models to simulate urban runoff and water quality in the Aberjona River. The data collected was also compared to information from other lakes and streams and water quality criteria as described later in this report. Again, details on the analytical methods used are presented in the Main Report.

PROJECT REPORTING

The results of this project are important at the local, regional, state and federal levels, but the objectives of each with regard to pollution control vary to some degree. Local citizens and officials are interested in learning about the major sources of pollution in their community and the Watershed, as well as what can be done to improve local water quality. State and regional agencies share these concerns but also want to consider the implications of the results for other areas and the transfer of modelling techniques. At the national level, this project's results will be added to a growing data base used to report back to Congress on the magnitude of stormwater problems nationwide.

These varying objectives require different levels of detail in terms of the information presented, making it difficult to write one report which will effectively meet everyone's needs. Consequently, two reports have been written: the Main Report which details the results of the study and the monitoring and data analysis techniques used, and this, the Summary Report, which presents the major findings of the study.

In addition to these two volumes, our consultants, Camp Dresser and McKee, Inc. (CDM), have prepared a number of reports dealing with various aspects of the project as listed here:

CDM, 1980a. Upper Mystic Lake NURP Case Study - Precipitation Analysis.

___, 1980b. Aberjona River Basin Water Quality Summary.

___, 1981b. Coliform Correlation Analysis Using Existing Data.

___, 1982. Upper Mystic Lake Nationwide Urban Runoff Program Case Study.

2. DESCRIPTION OF THE WATERSHED

The Upper Mystic Lake Watershed covers approximately 28 square miles and is the northern portion of the Mystic River Basin which is located in eastern Massachusetts extending northeast from Boston Harbor. The Watershed covers portions of nine communities: Arlington, Burlington, Lexington, Medford, Reading, Stoneham, Wilmington, Winchester, and Woburn (see Figure 1). Two major interstate highways, Routes 93 and 95, cross the Watershed in its northern and eastern sections, as shown in Figure 2.

GEOLOGY

The Upper Mystic Lake Watershed, like most of eastern Massachusetts, is underlain by metamorphic and igneous rocks, primarily granite and gneiss, formed during the Precambrian and Paleozoic Ages, one billion to 300 million years ago. After formation, this bedrock went through a long period of uplifting and dissection by stream erosion. This process was interrupted by the glaciers of the Pleistocene Epoch, about 14,000 years ago. The valley which existed prior to glaciation was filled by glacial deposits with a maximum recorded depth to bedrock within the Upper Mystic Lake Watershed of 165 feet. These deposits are known as the Fresh Pond Buried Valley. Two types of deposits predominate; outwash and till. Outwash was deposited by glacial meltwater and consists of stratified and sorted sands, gravel and silts. Till, on the other hand, was deposited directly by the glaciers and is unsorted clay, sand, and gravel with cobbles and boulders.

PRECIPITATION

Historic precipitation data within the Upper Mystic Lake Watershed is limited. A permanent station in Reading has recorded daily data for 26 years and hourly data for 11 years. The Metropolitan District Commission (MDC) has maintained a daily recorder at Spot Pond, 2 miles northeast of the Upper Mystic Lake, since 1900. The most extensive record of

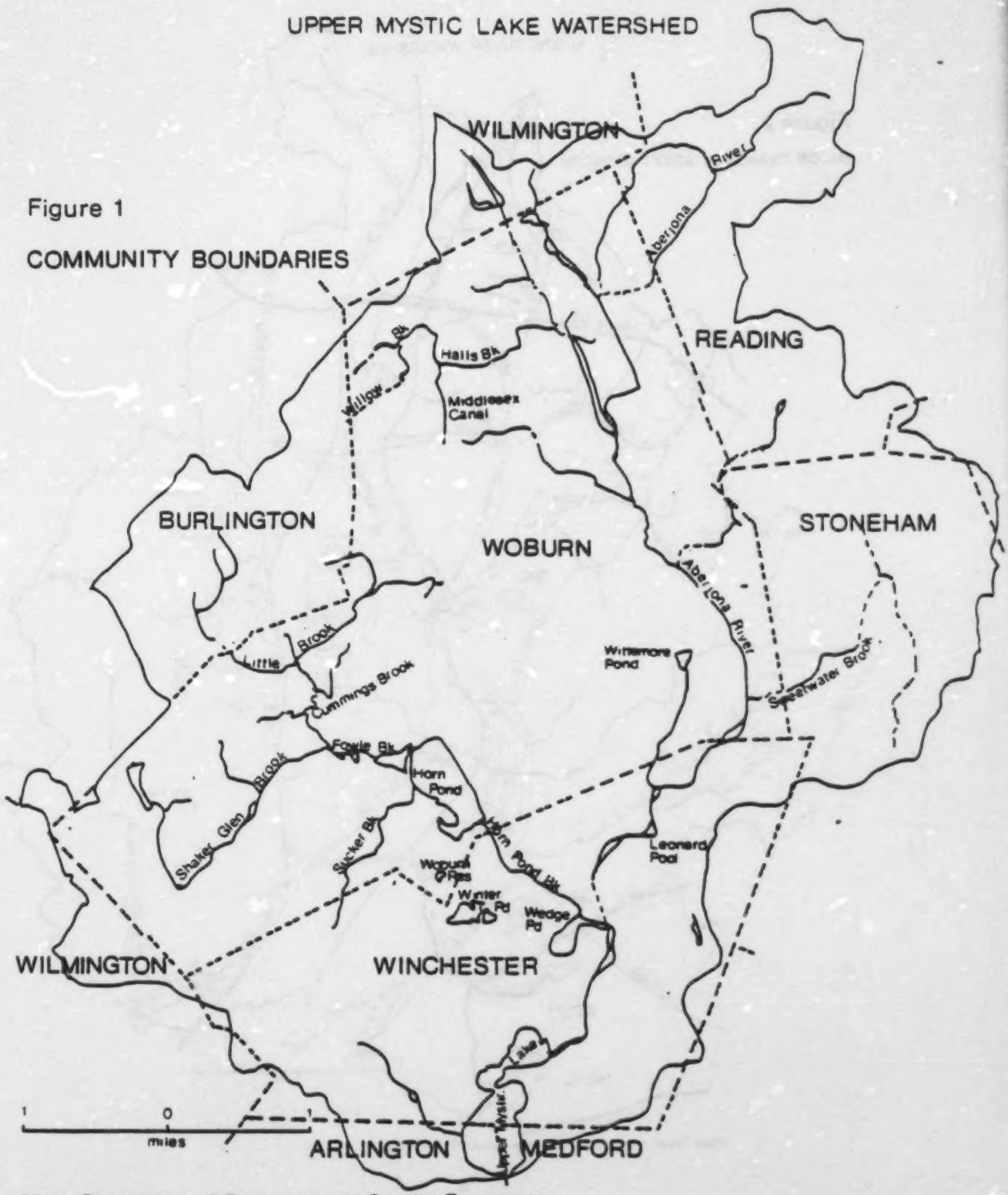


Figure 1

COMMUNITY BOUNDARIES

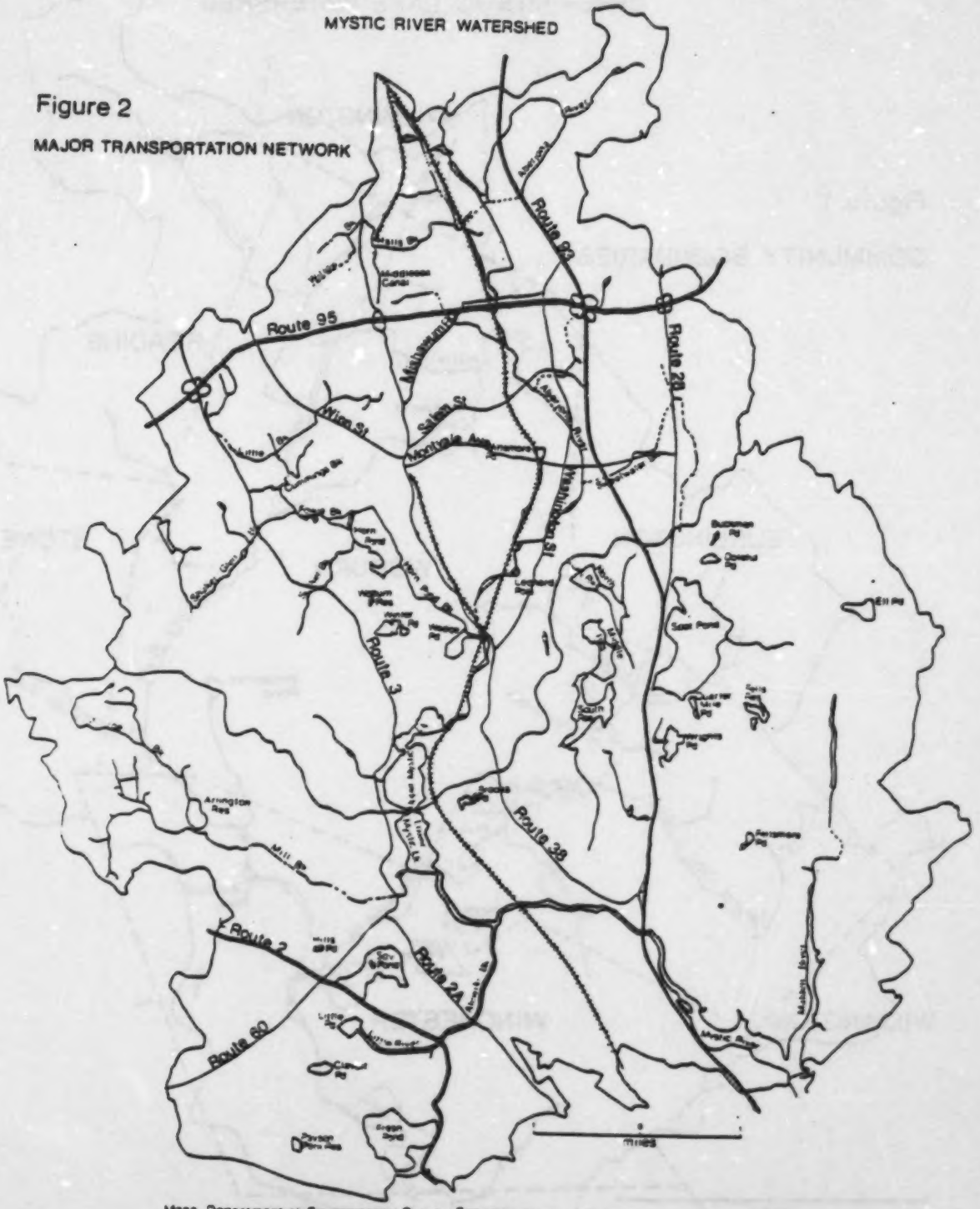
Mass. Department of Environmental Quality Engineering

9

MYSTIC RIVER WATERSHED

Figure 2

MAJOR TRANSPORTATION NETWORK



Mass. Department of Environmental Quality Engineering

Reproduced from best available copy.

hourly data maintained in the Boston area is the National Weather Service station at Logan Airport, about 9 miles southeast of the Lake, which has 43 years of record.

The long-term annual and monthly precipitation values at all three stations are shown in Table 2. As seen there, the annual averages vary from 41.50 to 46.87 inches. Reading and Spot Pond values compare better than does the Logan data, probably due to coastal influences at the latter. All the sites show a fairly even distribution of total rainfall throughout the year, with June and July being the driest months and November and December the wettest.

Three additional recording rain gauges were set up in the Watershed for the duration of the project's sampling program. Additionally, the Mystic River Watershed Association organized a volunteer daily rainfall data collection program throughout the Watershed. The data collected demonstrated a great deal of variability in rainfall across the Watershed. Table 3 presents monthly totals for July, August and September of 1981.

SURFACE WATERS

The Aberjona River is the major tributary to the Upper Mystic Lake with a drainage area of 25.6 square miles. Its tributaries include Halls Brook, Sweetwater Brook, Horn Pond Brook, and Whittemore (also known as Walker's) Pond Brook.

The Aberjona River originates in a marshy area north of Route 129 in Reading. It flows south, branches, passes under Route 93, meets drainage from two small ponds just south of the Woburn-Wilmington boundary, and is now channelled down the length of Commerce Way in Woburn. Halls Brook and its tributary, Willow Brook, originate in a Burlington wetland and drain 2.9 square miles. Halls Brook and the Aberjona River formerly flowed into Mishawum Lake, but industrial development in that area has altered that drainage pattern. Mishawum Lake has been largely filled and replaced by Halls Brook storage area. The Aberjona has been routed around this area and now joins Halls Brook at the storage area outlet immediately north of Mishawum Road.

After the river passes under Route 95, it meanders through several marshlands before entering Burbank Pond. In previous years, the Aberjona's flow was impounded and Burbank Pond served as a cranberry bog. Sweetwater Brook, which has a predominantly urban drainage area of 2.3 square miles, joins the Aberjona from the east just south of Montvale Avenue. Below Sweetwater Brook the Aberjona continues to travel south in an open channel and over three small dams until reaching Winchester High School's athletic field, which was once Aberjona Pond. The Pond has been filled and the Aberjona flows through three culverts beneath the field.

Below the athletic field, Horn Pond Brook, which has a drainage area of 10.0 square miles, joins the Aberjona River. The outer parts of the Horn Pond Brook Watershed are drained by Shaker Glen, Cummings and Sucker Brooks. Horn Pond covers an area of roughly 120 acres and is used for recreation and as a source of water supply recharge for Woburn's wells.

Table 2: LONG TERM PRECIPITATION CHARACTERISTICS

Month	Reading		Spot Pond		Logan International Airport	
	Average Precipitation in inches	Average Precipitation as % total yearly	Average Precipitation in inches	Average Precipitation as % total yearly	Average Precipitation in inches	Average Precipitation as % total yearly
January	4.16	9.1	4.07	8.7	3.64	8.8
February	3.56	7.8	3.84	8.1	3.38	8.1
March	4.28	9.4	4.26	9.1	3.82	9.2
April	3.77	8.2	3.95	8.4	3.55	8.6
May	3.73	8.2	3.90	8.3	3.25	7.8
June	3.00	6.6	3.15	6.7	3.12	7.5
July	2.80	6.1	3.14	6.7	3.15	7.6
August	3.71	8.1	3.80	8.1	3.61	8.7
September	3.67	8.0	3.49	7.4	3.22	7.8
October	3.79	8.3	3.69	7.9	3.24	7.8
November	4.67	10.2	4.95	10.6	3.84	9.2
December	4.57	10.0	4.65	10.0	3.69	8.9
	45.71	100.0	46.87	100.0	41.50	100.0

Table 3: SPATIAL RAINFALL VARIABILITY

	Cumulative Rainfall (inches) - 1981		
	July	August	September
DEQE GAUGES			
Winchester	3.76	1.90	3.26
Stoneham	4.64	1.98	2.9
Burlington	3.98	1.06	3.55
MRWA STATIONS			
Arlington	5.4	1.7	----
Winchester	3.8	1.8	3.3
Woburn	5.5	0.9	3.1
Woburn	4.3	0.7	----
LONG-TERM STATIONS			
Reading	5.39	1.25	4.18
Spot Pond	4.22	1.64	2.25

Below its confluence with Horn Pond Brook, the Aberjona enters Judkins Pond and Mill Pond in Winchester Center. The outlet of Mill Pond is a semi-circle step spillway with a fall of approximately six feet.

The Aberjona continues south past the U.S. Geological Survey's (USGS) flow gauging station. The USGS has recorded continuous flow rates at the Aberjona River gauge since 1939. The average flow rate is 27.5 cubic feet per second (cfs) with a maximum flow of 1,330 cfs on January 25, 1979 and a minimum daily average of .25 cfs on October 10, 1950 (USGS, 1980c). As the Aberjona nears its end, it makes a final bend to the west, gaining depth and width as it enters the Upper Mystic Lake.

In addition to the Aberjona, there are two inlets to the Lake (see Figure 3). The West Shore Inlet which drains 480 acres and the Boat Club Inlet draining 495 acres. The remaining Watershed area, 540 acres, drains directly into the Lake.

The Upper Mystic Lake itself has three basins: two shallow northern basins or forebays and a main deep southern basin. The entire lake covers 167 acres with the main basin having 102 acres or 61% of the entire area. The depths recorded in our field study are shown in Figure 3, with the main basin having a maximum depth of approximately 90 feet. The shoreline distance around the Lake is 2.8 miles. Additional physical data for the Lake, including volumes, are shown in Table 4.

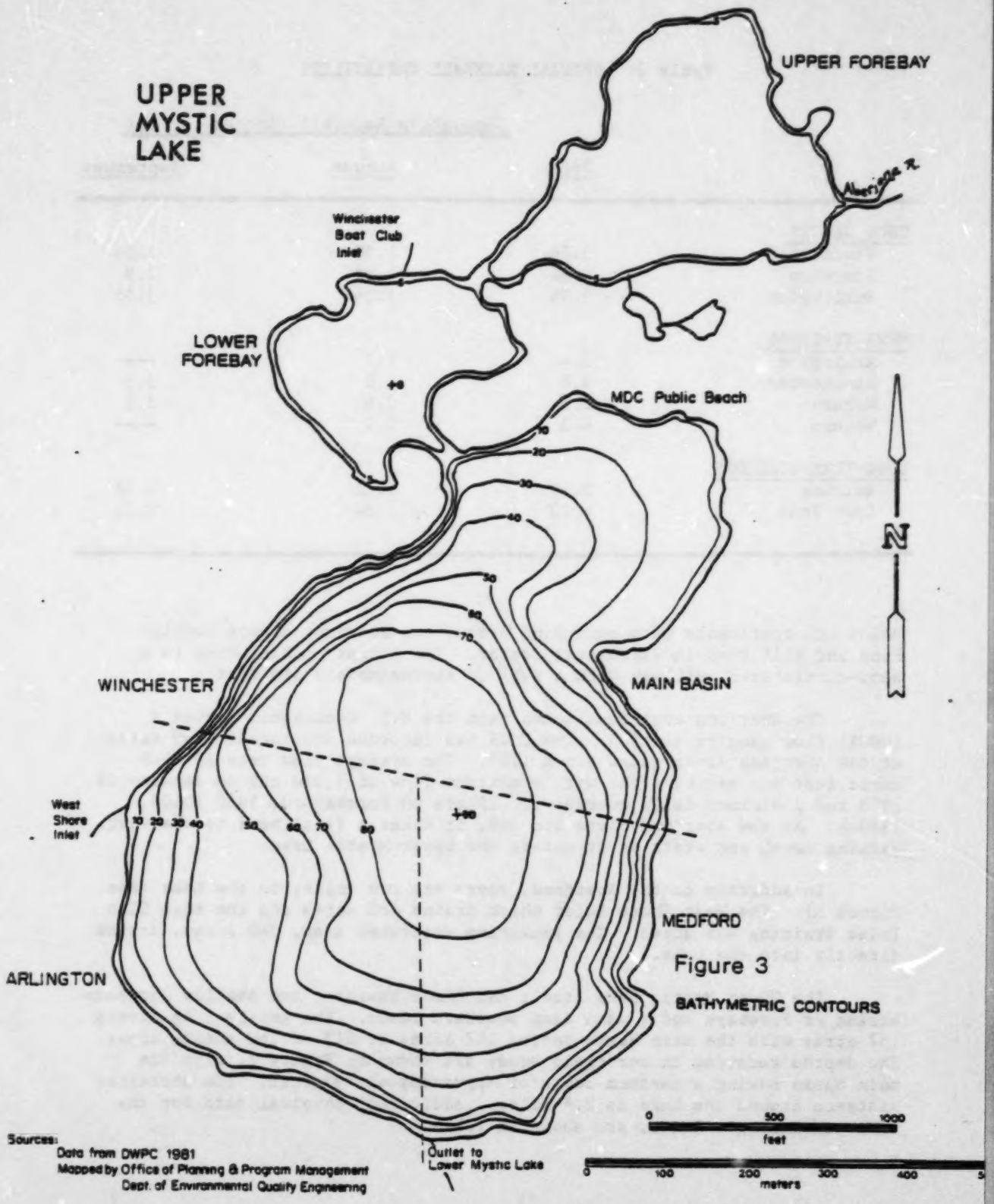


Figure 3

BATHYMETRIC CONTOURS

Sources:
Data from DWPC 1981
Mapped by Office of Planning & Program Management
Dept. of Environmental Quality Engineering

Table 4: UPPER MYSTIC LAKE PHYSICAL DATA

	Total	Main Basin	Lower Forebay	Upper Forebay
Area(acres)	166	126	14.5	25.5
Maximum Depth(feet)	90	90	8	6
Maximum Length(feet)		3,450	490	899
Maximum Width(feet)		2,150	621	572
Volume(cubic feet)	273,000,000	264,000,000	3,800,000	5,200,000
Percent Volume		97%	1%	2%

Based on this physical data and the flow data available, the retention time of the Lake, or the time it takes water entering at the Aberjona River to go through the Lake to the outlet, was calculated. Retention time is extremely important when considering water quality impacts, since it determines how fast pollutants will move through the lake and how much suspended matter will settle to the lake bottom.

On an annual basis the retention time is about 104 days or, alternately, the water in the Lake is replaced 3.5 times a year. The two forebays alone have a combined retention time of 8 days. Just considering summer conditions, during dry weather the flushing rate drops to 2.3 times a year or less than once a summer. Likewise, the retention time in the forebays is extended to approximately 19 days. Under summer storm conditions, tributary flows can increase considerably in a matter of hours shortening the retention time in the forebays. As demonstrated during our field studies, when Aberjona flows jumped from 8 cfs to 62 cfs in 6 hours, river water passed through the two forebays in less than two days.

The path water takes as it moves through the Lake is also very important in considering retention time and water quality. If, for example, the Aberjona water entering the Lake flows in a direct line through the forebays, the retention time would be considerably less than if it mixes with the water in the forebays. The retention time calculations discussed above assumed complete mixing, and this was verified by a study of the flow patterns in the Lake. Wind also influences flow patterns. Our field studies showed that a prevalent north wind tends to hold water in the northern part of the forebays and main basin. Water temperature also influences flow and will be discussed later in this report.

GROUNDWATER

Groundwater is the subsurface water that is found beneath the water table in saturated soils and geologic formations. The groundwater located in the Upper Mystic Lake Watershed is found in the large valley fill aquifer known as the Fresh Pond Buried Valley. While this project did not study groundwater in the Watershed, it is important to remember that surface waters and groundwater are interconnected. Streams and lakes may contribute to

groundwater or groundwater may feed surface water. In this Watershed groundwater is the major source of water to the Aberjona River during dry weather; consequently, the quality of the Aberjona during those conditions reflects groundwater quality. This dry weather flow is called baseflow.

HISTORICAL DEVELOPMENT

Many changes have taken place in the Upper Mystic Lake Watershed since the Massachusetts Bay Colony was founded in 1630. The area was originally settled by Algonquin Indians. It is believed that these Indians are responsible for the name of the Mystic Lakes, despite its change from the original "Missi-Tuk". Translated, these words mean "great" and "a river whose waters are driven by waves". This appropriately described the Lakes which, at that time, were tidal.

Farming was the primary land use in the Watershed for many years. The 1803 completion of the 27 mile-long Middlesex Canal, spanning from Charlestown to Lowell, encouraged the transition from agriculture to industry. In 1835, the opening of the Boston and Lowell Railroad induced further industrial growth, but Middlesex Canal became obsolete. The Canal was kept in operation until 1853. Many chemical companies were established along the tracks of the railroad, particularly in the upper part of the Watershed, the first being the Merrimack Chemical Company in Woburn in 1853. These industries used scrap materials from Boston slaughterhouses to produce the dyes used by textile companies in Lowell. Tanners, shoe manufacturers, and food processors were among the other major industries located in the area at this time.

The next big change in the Watershed came in 1864 when the dam between the Upper and Lower Mystic Lakes was built. This allowed the Upper Mystic Lake to be maintained as a freshwater lake. The Lake then became a source of drinking water. Approximately 30 million gallons of water per day were pumped from the Lake to the College Hill Reservoir in Medford. From there the water was distributed to Charlestown and later to Somerville. This use of the Lake continued until the 1890s when pollution from the industries upstream stopped its use not only as a water supply source, but as a recreational area too. Throughout the early 1900s the quality of the Lake oscillated. Despite periodic bathing prohibitions, several recreational facilities were constructed along the Lake. The Metropolitan Park Commission acquired 2½ miles of shoreline and developed a parkway between Winchester and Medford, and a recreational facility at Sandy Beach. Also, private boat clubs were established along the Lake.

The temporary closing of industries during World War I (1914-1918) improved the Lake's water quality; however, the polluting industries continued to function until the 1930s when the lure of cheap labor and modern equipment elsewhere prompted the shoe and textile industries to leave Massachusetts. With the closing of the Boston stockyards, many chemical companies were forced to shut down too. The loss of these industries encouraged communities in the northern portion of the Watershed to attract new "high technology" firms. Problems developed when these companies began to establish themselves on the same land previously used by the tanning and chemical companies and old waste

deposits were uncovered.

PRESENT AND FUTURE DEVELOPMENT

In the past two decades intensive urbanization has taken place in most areas of the Watershed. All communities except for Medford showed substantial increases in their populations, a trend which is expected to continue at a slower rate in the future. Table 5 shows the populations in the Watershed as of 1975, the change in population since 1950, and the projected growth rates.

Land use in the Watershed has reflected these population changes with single family homes being the predominant form of development (CDM, 1981a). Industrial and commercial growth followed the changing economic trends by moving away from water-intensive practices toward a technical service-oriented economy. The rapid development of land along major highways, such as Routes 93 and 95, is evidence of this transition. At present 57% of the Watershed area is residential development, 13% commercial/industrial, and 30% open space. This pattern of growth is expected to continue, especially in the northern sections of the Watershed where more undeveloped land exists.

Table 5: COMMUNITY POPULATION CHANGES IN THE UPPER MYSTIC LAKE WATERSHED

Community	1975* Population	Percent Change 1950-1970	Percent Change 1975-1995
Arlington	50,300	20.7	0.2**
Burlington	24,400	76.3	16.8
Lexington	32,500	83.9	10.8
Medford	60,800	- 2.6	3.6
Reading	23,700	60.9	28.7
Stoneham	22,000	56.7	11.4
Wilmington	17,500	143.0	7.1
Winchester	22,700	43.6	8.4
Woburn	35,200	82.5	18.2

* Data from 1980 census was not obtained but should now be available.
** Arlington's population has actually declined slightly in recent years.

Source: Resource Analysis, 1978.

3. WATER QUALITY GOALS

The identification of water quality problems in this study was based on a comparison of existing water quality conditions with the requirements for certain uses. This included both existing uses which may be threatened by water quality conditions and desired uses which are precluded by those conditions.

WATER QUALITY STANDARDS AND CRITERIA

The Massachusetts Water Quality Standards describe water quality requirements for surface waters in terms of their desired use. There are three classifications, but only two are presently of relevance to surface waters in the Upper Mystic Lake Watershed - Classes B and C (see Table 6). The Massachusetts Department of Environmental Quality Engineering's Division of Water Pollution Control (DWPC) has designated all surface waters in the Watershed as Class B, but their latest report indicates that all of the Aberjona River and its tributaries, as well as the Upper Mystic Lake itself, are below this desired quality level. In most cases they were also below the "C" level, and described as unsatisfactory in the most recent DWPC rating of 1978 (see Table 7). Based on the data collected under this project, conditions have for the most part not improved significantly since that time. In addition, the State Sanitary Code includes regulations for bathing water quality for beaches similar to Class B standards. Any public areas where swimming is permitted must be sampled for bacteria at least twice per month during the bathing season, but weekly monitoring is recommended.

The Metropolitan District Commission has an established policy for bathing water quality. If a weekly fecal coliform sample taken at a MDC beach exceeds 500 colonies/100 ml, the beach will be posted to warn that swimming may be hazardous to human health and resampled. If the coliform count ranges from 201 to 500 colonies/100 ml, the beach will be resampled but not posted (DiPietro, 1982).

Reproduced from best available copy.

Table 6: WATER QUALITY CLASSIFICATION FOR INLAND WATERS (M.G.L. Ch. 21, §27)

Class A - Waters assigned to this class are designated for use as a source of public water supply.

Class B - Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife; and for primary and secondary contact recreation.

Class C - Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife; and for secondary contact recreation.

Standards

For Class B Waters:		For Class C Waters:	
Parameter	Criteria	Parameter	Criteria
1. Dissolved Oxygen	Shall be a minimum of 5.0 mg/l in warm water fisheries and a minimum of 6.0 mg/l in cold water fisheries.	1. Dissolved Oxygen	Shall be a minimum of 5.0 mg/l in warm water fisheries and a minimum of 6.0 mg/l in cold water fisheries.
2. Temperature	Shall not exceed 83°F (28.3°C) in warm water fisheries or 68°F (20°C) in cold water fisheries, nor shall the rise resulting from artificial origin exceed 4.0°F (2.2°C).	2. Temperature	Shall not exceed 83°F (28.3°C) in warm water fisheries or 68°F (20°C) in cold water fisheries, nor shall the rise resulting from artificial origin exceed 4.0°F (2.2°C).
3. pH	Shall be in the range of 6.5-8.0 standard units and not more than 0.2 units outside of the naturally occurring range.	3. pH	Shall be in the range of 6.5-9.0 standard units and not more than 0.2 units outside of the naturally occurring range.
4. Fecal Coliform Bacteria	Shall not exceed a log mean for a set of samples of 200 per 100 ml, nor shall more than 10% of the total samples exceed 400 per 100 ml during any monthly sampling period, except as provided in Regulation 2.1.	4. Fecal Coliform Bacteria	Shall not exceed a log mean for a set of samples of 1000 per 100 ml, nor shall more than 10% of the total samples exceed 2,500 per 100 ml during any monthly sampling period, except as provided in Regulation 2.1.

Source: Massachusetts Department of Environmental Quality Engineering, 1978.

Table 7: UPPER MYSTIC LAKE WATERSHED WATER QUALITY CLASSIFICATION

Stream Segment	1980 Classification	1978 Condition
Aberjona River:		
- Headwaters to Hall's Brook	B	C
- Hall's Brook to Mishawun Road	B	U
- Mishawun Road to Mill Street	B	U
- Mill Street to Sweetwater Brook	B	U
- Sweetwater Brook to Washington Street	B	U
- Washington Street to Horn Pond Brook	B	U
- Horn Pond Brook to Upper Mystic Lake Inlet	B	U
Upper Mystic Lake:		
- Inlet to Outlet	B	U

Source: Massachusetts DEQE, 1981.

The standards discussed above are designed primarily to protect humans from contracting bacterial infections, and to ensure that basic habitat requirements for fish populations exist. While these are concerns of the Mystic Urban Runoff Project, the impacts of urban runoff on aquatic environments may also include effects attributed to contaminants for which numerical standards are not specifically listed in the State water quality and sanitary regulations. The former regulations do, however, provide for consideration of other parameters, using EPA criteria as guidelines. Currently available EPA criteria for a number of additional contaminants were compared to the water quality data collected in this study (U.S. EPA, 1976, 1980a).

LOCAL WATER QUALITY GOALS

As previously discussed, the DEQE Division of Water Pollution Control has designated the Upper Mystic Lake Watershed as having Class B surface waters, reflecting the State and Federal goal of reaching and maintaining fishable and swimmable waters. Local support was strong at the time the designations were being determined, and is in part responsible for the basinwide B rating. It was made apparent through surveys that the public wanted to use surface waters for recreational purposes.

As part of this project, a questionnaire designed to obtain current information relevant to present and desired uses of local surface water was distributed to Conservation Commissions, Planning Boards and Recreation Departments in 1981. The responses indicated a definite desire to preserve and improve the quality and recreational value of the Watershed's surface waters. Table 8 presents survey results regarding current use and Table 9 presents additional future uses desired. Figure 4 shows publicly owned lands adjacent to major water bodies.

Table 8: USES OF MAJOR WATER BODIES - SURVEY RESULTS

Surface Water Area	Use(s)	Surface Water Area	Use(s)
Aberjona River Headwaters (to Route 128)	Conservation Area Flood Control Park or Playground Skating	Horn Pond Brook	Conservation Area Flood Control
Halls Brook	Conservation Area Flood Control	Winter Pond	Non-Motor Boating Skating Warm Water Fishing
Middlesex Canal	Flood Control Historical Area Non-Motor Boating Park or Playground Skating Warm Water Fishing	Wedge Pond	Cold Water Fishing Flood Control Non-Motor Boating Park or Playground Skating Swimming Warm Water Fishing
Aberjona River (Route 128 to Sweetwater Brook	Conservation Area Flood Control Skating	Long Pond	Conservation Area Skating
Aberjona River (Sweetwater Brook to Wedge Pond)	Conservation Area Flood Control Park or Playground	Aberjona River (Wedge Pond to Upper Mystic Lake)	Conservation Area Flood Control Park or Playground
Leonard Pool	Park or Playground Skating Swimming	Judkins Pond	Conservation Area Park or Playground Warm Water Fishing
Shaker Glen Brook	Cold Water Fishing Conservation Area Flood Control Skating Warm Water Fishing	Mill Pond	Conservation Area Flood Control Park or Playground Warm Water Fishing
Horn Pond	Cold Water Fishing Conservation Flood Control Motor Boating Non-Motor Boating Skating	Upper Mystic Lake	Conservation Area Flood Control Non-Motor Boating Park or Playground Skating Swimming Warm Water Fishing

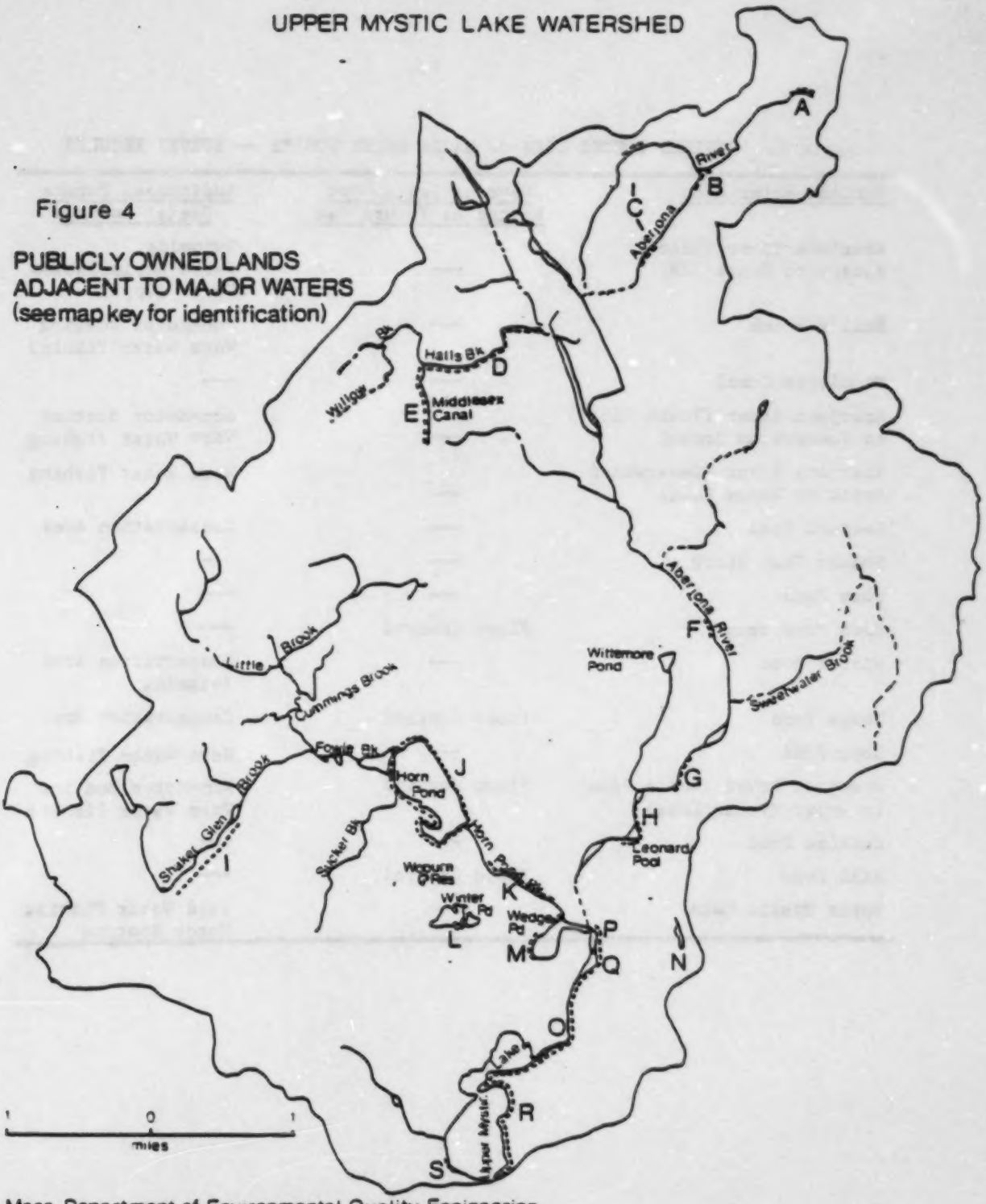
Table 9: DESIRED FUTURE USES OF MAJOR WATER BODIES — SURVEY RESULTS

Surface Water Area	Current Use(s) Not Listed As Future Use	Additional Future Use(s) Desired
Aberjona River (Headwaters to Route 128)	—	Swimming Waste Assimilation Water Supply
Hall's Brook	—	Non-Motor Boating Warm Water Fishing
Middlesex Canal	—	—
Aberjona River (Route 128 to Sweetwater Brook)	—	Non-Motor Boating Warm Water Fishing
Aberjona River (Sweetwater Brook to Wedge Pond)	—	Warm Water Fishing
Leonard Pool	—	Conservation Area
Shaker Glen Brook	—	—
Horn Pond	—	—
Horn Pond Brook	Flood Control	—
Winter Pond	—	Conservation Area Swimming
Wedge Pond	Flood Control	Conservation Area
Long Pond	—	Warm Water Fishing
Aberjona River (Wedge Pond to Upper Mystic Lake)	Flood Control	Non-Motor Boating Warm Water Fishing
Judkins Pond	—	—
Mill Pond	Flood Control	—
Upper Mystic Lake	—	Cold Water Fishing Motor Boating

UPPER MYSTIC LAKE WATERSHED

Figure 4

PUBLICLY OWNED LANDS
ADJACENT TO MAJOR WATERS
(see map key for identification)



Mass. Department of Environmental Quality Engineering

KEY TO FIGURE 4

A: Kurchian Woods, Reading

B: Linnaea Thelin Bird Sanctuary, Reading

C: Conservation Areas along the Aberjona River, Reading

D: Halls Brook Conservation Area, Woburn

E: Middlesex Canal Historic Area, Woburn

F: Cranberry Bog, Woburn

G: Conservation Area along the Aberjona River, Winchester

H: Davidson Park, Winchester

I: Shaker Glen Wildlife Wetlands, Woburn

J: Horn Pond Recreational Area, Woburn

K: Horn Pond Brook Conservation Area, Winchester

L: Winter Pond, Winchester

M: Palmer Playground, Winchester

N: Middlesex Fells Reservation, Winchester

O: Park along the Aberjona River, Winchester

P: Eliot Park, Winchester

Q: Mill Pond Park Area, Winchester

R: Upper Mystic Lake Recreational Area, Winchester/Medford

S: Window on the Mystic, Arlington

Factors affecting use impairment and specifics about water quality were also probed. Most respondents felt that poor water quality impaired the desired use of waters within the basin, with pollution stemming from both upstream and local sources. Some water bodies suffered from neglect; others were over-used. Other common problems affecting use dealt with inaccessibility to the water and the lack of adequate recreational facilities. Low flow in the Aberjona River was also felt to impair desired uses. Table 10 summarizes the local opinions of problems affecting major water bodies in the basin. Respondents were also asked what factors they felt had helped to improve water quality over the past five years. Responses included federal and state regulations, local regulations and public awareness.

From these views, the local officials have indicated a continuing desire to achieve Class B waters. This opinion gives support to the objectives of the Mystic Urban Runoff Project, and will provide backing for the final recommendations.

Table 10: FACTORS AFFECTING USES OF MAJOR SURFACE WATER BODIES - SURVEY RESULTS

Surface Water Area	Factor(s) Impairing Use
Aberjona River (Headwaters to Route 128)	Low Flow Over-Use Poor Water Quality • Local Pollution Sources
Hall's Brook	Poor Water Quality
Aberjona River (Route 128 to Sweetwater Brook)	Poor Water Quality
Aberjona River (Sweetwater Brook to Wedge Pond)	Inadequate Recreational Facilities Insufficient Access/ Surrounding Land Primarily Privately Owned Low Flow Neglect Poor Water Quality • Local Pollution Sources • Upstream Pollution Sources
Leonard Pool	Low Flow Neglect Over-Use Poor Water Quality
Shaker Glen Brook	Low Flow
Horn Pond Brook	Neglect
Winter Pond	Inadequate Recreational Facilities Inadequate Surface Area Insufficient Access/ Surrounding Land Primarily Privately Owned Poor Water Quality
Wedge Pond	Inadequate Recreational Facilities Neglect Poor Water Quality
Long Pond	Inadequate Recreational Facilities Insufficient Access
Aberjona River (Wedge Pond to Upper Mystic Lake	Inadequate Recreational Facilities Insufficient Access Low Flow Neglect Poor Water Quality • Local Pollution Sources • Upstream Pollution Sources
Judkins Pond	Neglect Poor Water Quality • Upstream Pollution Sources
Mill Pond	Inadequate Recreational Facilities Low Flow Neglect Poor Water Quality • Upstream Pollution Sources
Upper Mystic Lake	Insufficient Access/ Surrounding Land Primarily Privately Owned Over-Use • Local Pollution Sources • Upstream Pollution Sources

4. WATER QUALITY PROBLEMS

The water quality of a river or lake is a result of various natural conditions, such as the geology of the area, and man's activities including waste discharge and watershed development. In a water quality study such as this it is important to identify both the water quality problems and the sources of the pollutants. The focus of this chapter is on the water quality of the Upper Mystic Lake and the impact of existing conditions on the use of the Lake. However, to identify the causes of those problems, sources of pollution throughout the Watershed and quality conditions in the Aberjona River and West Shore and Boat Club Inlets were investigated and will be described here and in the next chapter.

EUTROPHICATION

Before considering the specific water quality problems of Upper Mystic Lake, it is important to understand the life history of lakes and annual cycles which occur.

The term eutrophic means well nourished and eutrophication is the addition of nutrients to a lake and the changes that occur over time as a result of that nourishment. Eutrophication is a natural aging process which occurs in all lakes over thousands of years. Man can, however, accelerate this process by increasing the supply of nutrients. Industrial and municipal waste discharge, urban runoff, and agricultural runoff as well as other sources can greatly increase nutrient loadings.

The process of eutrophication can be divided into several stages:

Oligotrophic - low in nutrients and organic matter, dissolved oxygen throughout the lake;

Mesotrophic - an intermediate stage; and

Eutrophic - high in nutrients and organic matter, low dissolved oxygen in deep waters, decreased depth.

Additionally, the eutrophic stage is characterized by excessive aquatic plant growth, decline in cold water fisheries due to limited oxygen supply, low transparency, mucky sediments, and changes in the types of plants and animals found. Eventually as the lake continues to fill in it becomes marshland and eventually dry land.

The Upper Mystic Lake is a long way from becoming a marsh, but is certainly in the eutrophic stage. Table 11 compares the Lake with a number of characteristics of oligotrophic and eutrophic lakes.

In addition to this life history, certain important changes occur in a deep lake such as the Upper Mystic on an annual cycle. These cycles are controlled, to a large extent, by the thermal or temperature characteristics of the lake.

In the spring and continuing throughout the summer, solar radiation heats the surface water of a lake but does not penetrate to the deeper water. The density of the warmer surface water is then less than that of the cooler, deeper waters, and the warm water forms a separate layer which floats on top and does not mix with the deeper water. This phenomenon is called thermal stratification. The upper layer, called the epilimnion, is usually well mixed by the wind, while the deep cold layer called the hypolimnion does not mix with the rest of the Lake. In between these two regions is a transition zone known as the metalimnion. During autumn, the surface waters begin to cool and as temperatures approach those of the bottom waters the layers begin to mix. Eventually by late autumn, the entire water column is the same temperature and all the lake water mixes. This mixing is called fall turnover. During winter if no ice forms, the lake remains completely mixed. If ice forms, the lake can stratify with colder surface waters floating on warmer deeper waters. This is generally known as reverse stratification. As spring approaches the water column becomes a uniform temperature again allowing mixing or spring turnover.

Associated with thermal stratification in eutrophic lakes is a depletion of oxygen in the bottom waters. Once the lake stratifies in the spring, virtually no dissolved oxygen enters the hypolimnion, yet oxygen is continually used during the breakdown of organic matter and chemical oxidation. This can result in a partial or total depletion of oxygen in all or part of the hypolimnion. The area without oxygen is called the anoxic or anaerobic zone. Below certain critical levels of dissolved oxygen the area becomes uninhabitable by fish and other aquatic organisms, and the release of certain pollutants from the sediments can also result. This is particularly important for fish which require cold water, since the deeper water with the required temperature may not have sufficient dissolved oxygen. When the lake turns over in the fall, oxygen is reintroduced to the bottom waters and pollutants which have accumulated from sediment release are mixed throughout the lake. Oxygen may become depleted again in the winter if reverse stratification occurs. The specific temperature and dissolved oxygen characteristics of the Upper Mystic Lake will be discussed in the next section.

Table 11: COMPARISON OF OLIGOTROPHIC & EUTROPHIC LAKES

	Oligotrophic	Eutrophic	Upper Mystic Lake (1981 field data)
Dissolved Oxygen in Deep Water (mg/l)	≥5.0	<5.0	<1.0
Transparency	High	Low	Low
Ammonia (mg/l)	<0.03	>0.03	0.30-4.9
Nitrate (mg/l)	<0.03	>0.03	0.7-4.4
Total Phosphorus (mg/l)	≤0.01	>0.01	0.01-0.62
Rooted Aquatic Weeds	Sparce	Abundant	Abundant
Phytoplankton	High diversity algae bloom rare absence of blue-green algae	Low diversity blooms frequent abundance of blue-green algae	Low diversity blooms frequent abundance of blue-green algae
Fisheries	Coldwater Species	Warmwater Species	Warmwater Species

MAJOR WATER QUALITY PROBLEMS

Water quality conditions in the Upper Mystic Lake Watershed generally fall short of Class B standards for fishable/swimmable waters and the quality desired by local residents. As discussed above, the Lake exhibits the classic symptoms of eutrophic conditions including high nutrient concentrations, abundance of aquatic vegetation, low transparency, depleted dissolved oxygen in the deep waters, and inability to support cold water fish. Several other problems were identified which are not necessarily associated with eutrophication including elevated levels of coliform bacteria, ammonia and certain metals.

After surveying the various potential sources of pollution in the Watershed, the sources of pollutants entering the Lake were grouped into four major categories:

(1) Urban Runoff - the water which comes off of lawns, rooftops, streets and other paved areas after a storm which can either travel directly to the surface waters (direct drainage) or be collected in stormwater collection systems and then discharged to surface waters;

(2) Sewer Overflows - there are a number of areas in the Watershed where surcharging sewers cause sewage to enter the stormwater collection system and be discharged to surface waters;

(3) Baseflow - the water which enters the Lake from the Aberjona and other inlets during dry weather (low flow conditions) which, for the most part, comes from groundwater as discussed earlier; and

(4) Release from Lake Sediments - sediments play an important role in the cycling of pollutants in the Lake acting as a depository or sink for pollutants entering the Lake and under certain conditions releasing those pollutants.

Table 12 summarizes the relative contribution of the various sources for a number of pollutants and will be referred to throughout this section. The Sweetwater sanitary contribution listed there refers to the discharge of sewage to Sweetwater Brook through 19 combined manholes in Stoneham. This is the most significant of the sewer problems identified and the only one whose contribution was quantified.

Pollutants can be measured as concentrations (weight/volume or weight/weight, e.g. milligrams/liter) or as loadings (weight/time, e.g. pounds/year). Loads are calculated by multiplying concentration by flow (e.g. pounds/gallon x gallons/day = pounds/day). This distinction is extremely important when analyzing a lake where pollutants can build up over time and consequently the total loading is extremely important. The values in Table 12 are percentages of the total loading to the Lake for each pollutant listed.

The remainder of this chapter will discuss the water quality conditions found during the sampling program related to the various problems mentioned

Reproduced from best available copy.

Table 12: SUMMARY OF UPPER MYSTIC LAKE POLLUTANT SOURCES - PERCENTAGE OF CALCULATED LOAD

	Aberjona River			Direct Drainage to the Lake							
				West Shore Inlet		Boat Club Inlet		Direct Drainage			
	Baseflow	Urban Runoff	Sweetwater Sanitary	Baseflow	Urban Runoff	Baseflow	Urban Runoff	Baseflow	Urban Runoff	Groundwater	Sediments
TSS	17.1%	37.7%	28.0%	0.3%	7.1%	0.1%	4.3%	0.2%	5.2%	*	*
BOD	29.9	59.3	6.7	0.5	1.0	0.4	1.1	0.4	0.7		
Total P	27.8	24.2	20.0	0.5	1.0	8.1	5.3	0.3	0.8	0.5%	11.6%
TKN	56.6	36.6	5.2	0.1	0.3	0.6	0.3	0.1	0.2	*	*
Nitrate	30.7	57.8	3.9	1.8	0.9	2.0	0.9	1.3	0.7	*	*
Ammonia	63.4	34.8	0.5	0.4	0.3	0.1	0.1	0.3	0.2	*	*
Aluminum	24.6	15.0	50.4	0.4	2.7	0.2	4.3	0.3	2.0	*	*
Arsenic	20.8	69.7	4.3	1.5	0.6	0.8	0.8	0.8	0.6	*	*
Copper	0	33.6	60.3	0.3	1.4	0.4	2.7	0.3	1.0	*	*
Iron	45.4	29.5	22.0	0.4	0.8	0.1	0.9	0.3	0.6	*	*
Lead	0	42.7	45.4	0	5.2	0.4	2.6	0	3.7	*	*
Manganese	19.6	76.0	3.4	0.1	0.1	0.1	0.2	0.1	0.1	*	*
Zinc	41.0	19.5	35.0	0.8	1.4	0.1	0.6	0.6	1.0	*	*

*Not calculated due to insufficient information.
TSS - total suspended solids; BOD - biochemical oxygen demand; Total P - total phosphorus;
TKN - total kjeldahl nitrogen

above and the contributing sources of pollution identified. The monitoring program extended from February to November of 1981. Figures 5 and 6 show the locations sampled during the study.

Temperature and Dissolved Oxygen

Temperature plays a major role in controlling the physical, chemical and biological characteristics of aquatic systems including stratification, solubility, chemical reaction rates and the metabolism of aquatic life. Likewise, certain dissolved oxygen levels are required to sustain aquatic life and its presence prevents the release of certain pollutants from sediments.

As discussed above, thermal stratification in eutrophic lakes generally results in a depletion of dissolved oxygen in the deep waters. Upper Mystic Lake begins to stratify in early spring and remains so until late November or early December. Figure 7 shows the June 25, 1981 temperature and dissolved oxygen profiles at the deepest sampling site (station 4) which are typical of the summer profiles recorded. Thermal stratification is clearly shown with surface temperature of 23°C (73.4°F) and a bottom temperature around 5°C(41°F). Dissolved oxygen levels begin to decrease at 15 feet and at thirty feet less than 1 mg/l was observed. This anoxic zone below 30 feet comprises approximately 50 percent of the entire lake volume.

Development of such a large anoxic zone is indicative of extreme oxygen demanding conditions. There are three major sources of oxygen demanding material in the Lake:

(1) Organic matter entering from the Aberjona River and inlets which is decomposed in the Lake consuming oxygen. Measured as biochemical oxygen demand (BOD), Table 12 shows urban runoff is a major source.

(2) High ammonia levels entering from the Aberjona are oxidized to nitrate in the Lake consuming oxygen. Much of this ammonia enters the Aberjona baseflow from an industrial site in Wilmington as discussed in the nitrogen section.

(3) Internal load of organic matter resulting from the abundant plant growth in the Lake. As this growth dies and settles it too is decomposed using oxygen.

The internal load could not be calculated from the field data collected but given the high productivity levels of the Lake this demand is undoubtably significant. Rough estimates of the oxygen demand from the two external sources indicates that the oxidation of ammonia may demand as much as three times the oxygen required for the breakdown of organics.

The significance of this anoxic zone is twofold. First, Class B water quality standards for cold water fish set a minimum of 6.0 mg/l (milligrams/liter) with temperatures below 20°C (68°F). In Upper Mystic Lake the temperature requirements are only met in deeper waters where oxygen requirements

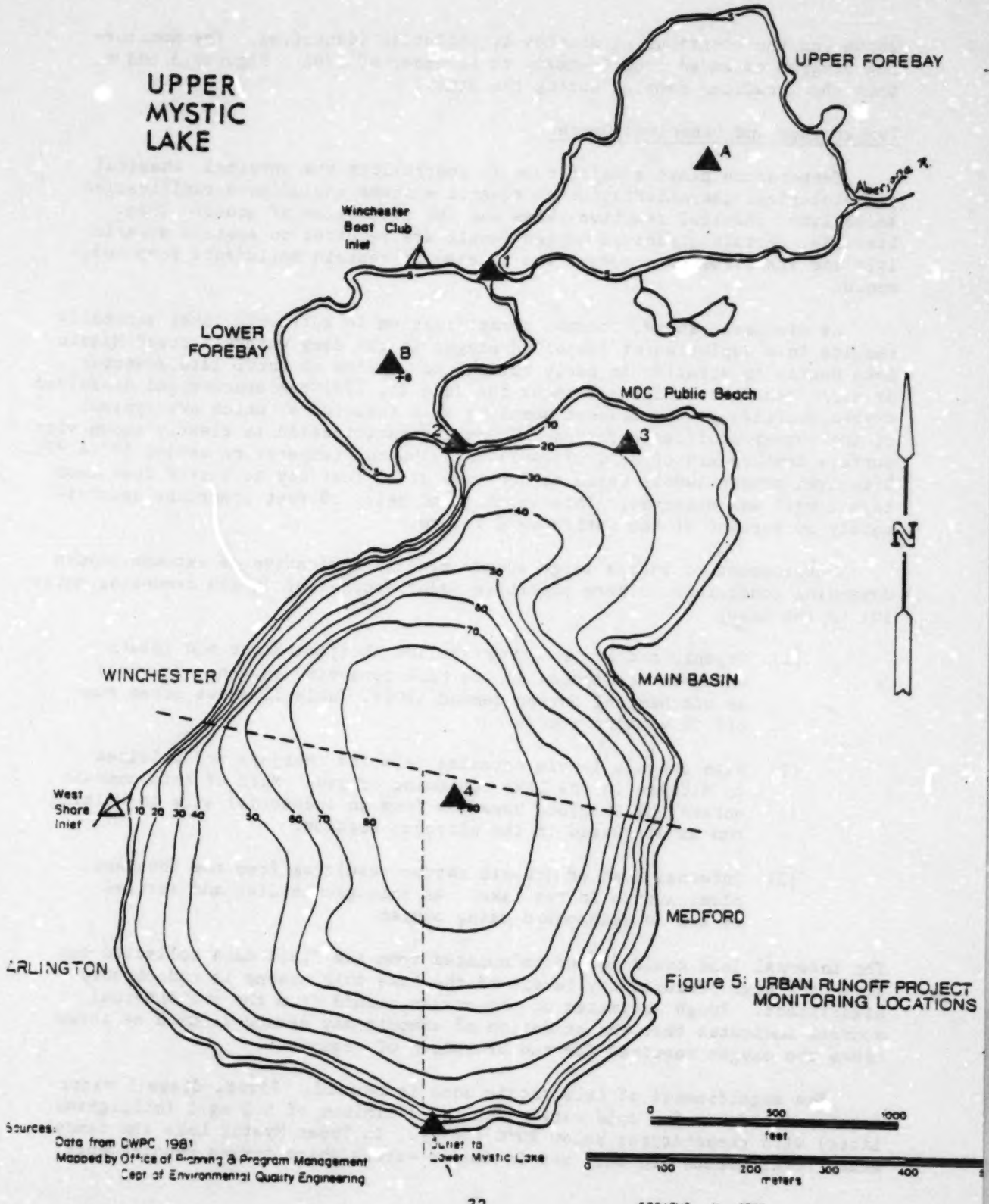


Figure 5: URBAN RUNOFF PROJECT MONITORING LOCATIONS

Sources:
Data from DWPC 1981
Mapped by Office of Planning & Program Management
Dept of Environmental Quality Engineering

SOBATHS IN FEET

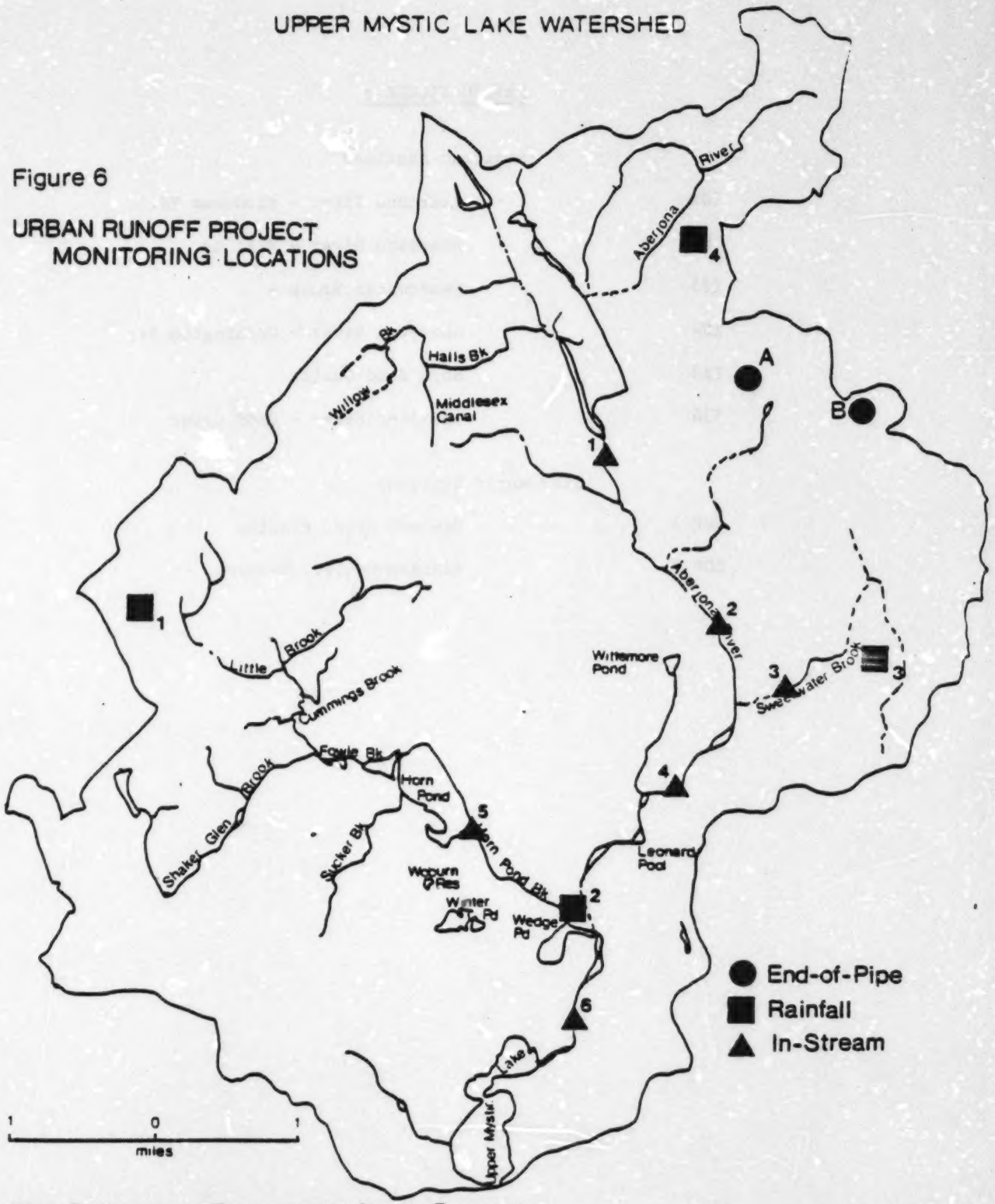


Figure 6

URBAN RUNOFF PROJECT
MONITORING LOCATIONS

Mass. Department of Environmental Quality Engineering

KEY TO FIGURE 6

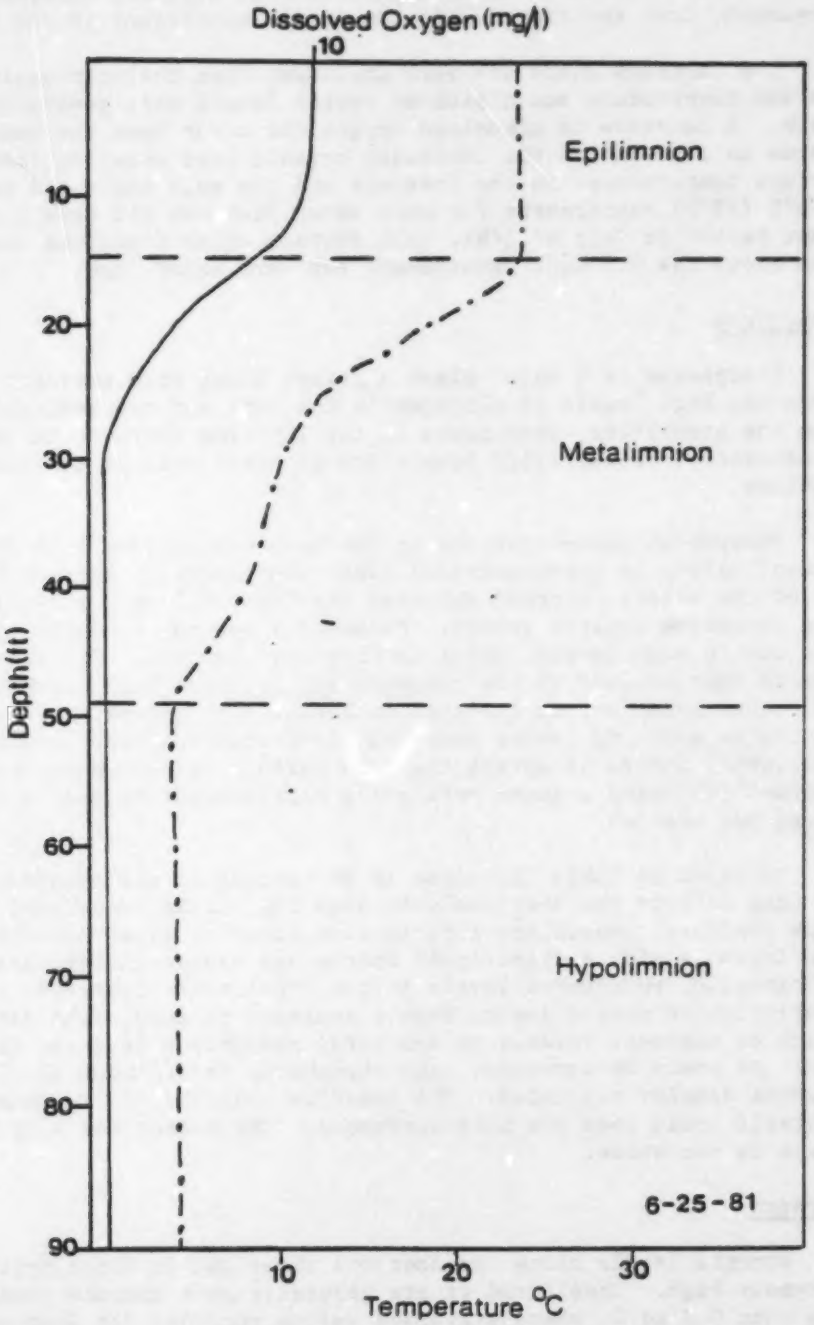
In-stream Stations

IS1	Aberjona River - Mishawum Rd.
IS2	Aberjona River - Mill St.
IS3	Sweetwater Brook -
IS4	Aberjona River - Washington St.
IS5	Horn Pond Outlet
IS6	Aberjona River - USGS Gauge

Stormwater Stations

EOP A	Hemlock Road, Reading
EOP B	Addison-Wesley, Reading

Figure 7: TYPICAL TEMPERATURE & DISSOLVED OXYGEN PROFILE



are not met. Secondly, there is evidence of sediment release of phosphorus, manganese, iron and zinc due to the anoxic conditions in the hypolimnion.

The forebays which are much shallower than the main basin did not stratify and temperature and dissolved oxygen levels were generally uniform with depth. A decrease in dissolved oxygen did occur near the sediments following storms as a result of the increased organic load entering from the Aberjona. Surface temperatures in the forebays and the main basin did not exceed the 28.3°C (83°F) requirement for warm water fish but did come close (28°C) during a hot period in July of 1981. All surface water dissolved oxygen values were above the 5.0 mg/l requirement for warm water fish.

Phosphorus

Phosphorus is a major plant nutrient along with nitrogen and carbon. Given the high levels of nitrogen in the Lake and the availability of carbon from the atmosphere, phosphorus is the limiting nutrient in the Lake and, consequently, productivity levels are directly related to phosphorus concentrations.

Phosphorus concentrations in the Lake ranged from 0.04 to 0.27 mg/l. Concentrations in uncontaminated lakes are generally between 0.01 and 0.03mg/l. All of the values recorded exceeded the EPA 0.025 mg/l guideline for controlling excessive aquatic growth. Phosphorus was particularly high in the forebays due to high levels coming in from the Aberjona. Excessive plant growth is also most evident in the forebays due to these high concentrations, and, for rooted aquatics, to the shallow depth. The forebays are actually functioning as settling basins removing particulate phosphorus and other suspended material before it enters the main basin. Higher concentrations were recorded following a storm reflecting high concentrations in the Aberjona during wet weather.

As shown on Table 12, close to 80 percent of the phosphorus load to the Lake is from the Aberjona with baseflow, urban runoff and the Sweetwater Brook sanitary connections contributing close to equal amounts. The Boat Club Inlet is also a significant source and sewage contamination is suspected. Additionally, phosphorus levels in the hypolimnion increased during the stratification period due to anoxic sediment release. The estimated contribution of sediment release to the total phosphorus load was close to 12 percent. As would be expected, high phosphorus levels were also found in the sediment samples collected. The baseflow contribution is unusually high and by itself could keep the Lake eutrophic. The reason for such high baseflow levels is not known.

Nitrogen

Ammonia levels along the Aberjona river and in Upper Mystic Lake are extremely high. Unpolluted rivers generally have ammonia concentrations less than 0.2 mg/l, whereas average values recorded for Aberjona river stations ranged from 2.2 to 11.0 mg/l and for inlake stations from 0.71 to 1.71 mg/l. These high levels are of concern because of the oxygen required

for oxidation of the ammonia and because unionized ammonia can be toxic to aquatic life.

Ammonia in aquatic systems occurs in both ionized (NH_4^+) and unionized (NH_3) forms. The relative amount of each is dependant on the temperature and pH of the water. EPA's toxicity criteria for unionized ammonia is 0.02 mg/l. Unionized values calculated for the Lake ranged from 0.001 to 0.230 mg/l. In all 8 data points or 16% of the surface water samples exceeded the criteria. All the violations occurred during hot and dry summer periods when surface water temperatures and pH were high.

Table 12 shows that 63 percent of the ammonia load is coming from Aberjona baseflow. In the upper reaches of the Aberjona dry weather concentrations were often twice those of wet weather. The ammonia is entering the Aberjona from Halls Brook which drains an industrial area in Wilmington where groundwater has been contaminated with ammonia.

Ammonia levels in the Aberjona and Lake have decreased significantly compared to historical data. In 1967 values of up to 83.3 mg/l were recorded in the Aberjona and in 1974 a maximum concentration of 0.7 mg/l unionized was recorded in the Lake. These reductions are the result of changing waste disposal practices on the Wilmington site as discussed in the next section.

Metals

The presence of metals within aquatic systems is of concern with regard to potential toxicity to aquatic life and the suitability of fish for human consumption. Metal content was measured at all the water sampling stations, and in lake sediments and fish flesh. The metals tested in this study were aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury (fish flesh and sediments only), nickel, tin and zinc.

Metal concentrations recorded in lake water were compared to chronic and acute toxicity criteria developed by EPA for the protection of aquatic life. These criteria may be overly protective for certain organisms since they are based on tests on a wide range of organisms. They should be considered general guidelines indicating a potential problem. Bioassays should be done to determine actual toxicity. Copper, lead, cadmium and zinc exceeded the chronic toxicity levels. These violations were distributed fairly evenly throughout the Lake and lead showed consistently higher violations during wet weather. Acute criteria were violated for aluminum, copper, iron and manganese. Of these aluminum and iron showed higher violations in wet weather. All of the manganese violations were in the hypolimnion, a direct result of anoxic sediment release. High metal levels were also found in the sediment.

Metal levels in fish flesh were also examined. Unfortunately the only Food and Drug Administration standard which exists is for mercury which was not exceeded. In their review of the data the Mass. Division of Fisheries and Wildlife considered the lead levels in bullheads high and recommended eating them in moderation, and concluded that otherwise, based on metals levels, there is no immediate threat to public health. The water quality data was

also compared to EPA criteria for the protection of human health from the ingestion of contaminated organisms - arsenic and lead exceeded these criteria. Again, these criteria are rough guidelines indicating a potential problem.

The relative sources of each of these metals varies, as shown on Table 12, with baseflow being a major source of iron, zinc and, to a lesser extent, aluminum; urban runoff a major source of manganese, lead, iron, copper, and arsenic; and the Sweetwater Brook sanitary connection a major source of aluminum, copper, lead, and zinc. Based on increased concentrations observed in the hypolimnion during stratification, the sediments are a source of manganese, iron and zinc.

Coliform

In waters used for recreation, contamination with disease-causing organisms is a major concern. The most common source of these pathogens is sewage. Coliform bacteria which are not harmful, are used as indicator organisms to detect contamination, as they usually outnumber and live longer than pathogens. Thus, the standards established for Class B waters and for bathing areas are designed to protect public health by limiting allowable coliform levels. While total coliform standards exist fecal coliform is considered a better indicator. The class B fecal coliform standard is a monthly logarithmic mean of 200/100 ml. In Upper Mystic Lake, the MDC collects weekly coliform samples at Sandy Beach during the swimming season.

As mentioned earlier sewage contamination of surface waters is a major problem in the Watershed. In Stoneham nineteen combined manholes periodically cause sewage discharge to Sweetwater Brook. Fecal coliforms levels of up to 1 million with an average of 178,000/100 ml were recorded in Sweetwater Brook during wet weather. As a result levels in the Aberjona downstream of where Sweetwater Brook enters are also high. Average wet weather fecal levels at the USGS gauge in Winchester were 50,000. Fecal coliform levels above the 200 coliform/100 ml were found in approximately one-third of the samples tested in the upper and lower forebays of the Lake and occasionally near the Lake outlet. In addition Sandy Beach exceeded the MDC fecal coliform criteria in July of 1982 and warnings that swimming may be hazardous to public health were posted for several days.

Studies have pointed to several areas where sewage is entering surface waters. Most comes from the combined manhole overflows to Sweetwater Brook, but six areas in Winchester's sewer line also occasionally surcharge. Two of these sites discharge directly to the Lake. Inadequate capacity in the sewer line located along Route 3 causes overflows to the stormwater line which drains to the lower forebay. Samples collected from the Route 3 stormwater outfall during wet and dry weather reflected this problem. Additionally a stormwater outfall between the two forebays is used as a relief line for the inverted siphon in the sewer line which runs under the Lake.

Two other areas of concern were indicated from test results. Elevated bacteria levels were found in the Boat Club Inlet and at the Lake outlet, but

the sources of contamination were not identified. An investigation of the Boat Club Inlet led to sampling of the stormwater line which drains to the inlet upstream of Everett Avenue. High coliform counts were detected in several areas, but they were still below levels detected at Everett Avenue indicating that an additional problem exists at some point along the inlet. High bacteria counts were also recorded at the outlet of the Lake. Complaints made by a member of the Medford Boat Club pointed to sewage contamination from an unidentified pipe along the shoreline. Possibly this was due to sewer line overflows to the stormwater line in Arlington. Further investigation of these two problems is needed to identify their sources.

There may be additional sources of coliform contamination which are undetected at this time. Urban runoff contributed to the bacteria load during wet weather but comparatively was much less significant than the sanitary sources. The Sweetwater Brook sanitary contribution was by far the greatest source. Separation of the sewer and stormwater lines in Stoneham was estimated to reduce mean total coliform concentrations at the USGS gauge by 66% (CDM, 1982). However, the other sources should not be ignored. Their proximity to the Lake makes them a significant threat to public health.

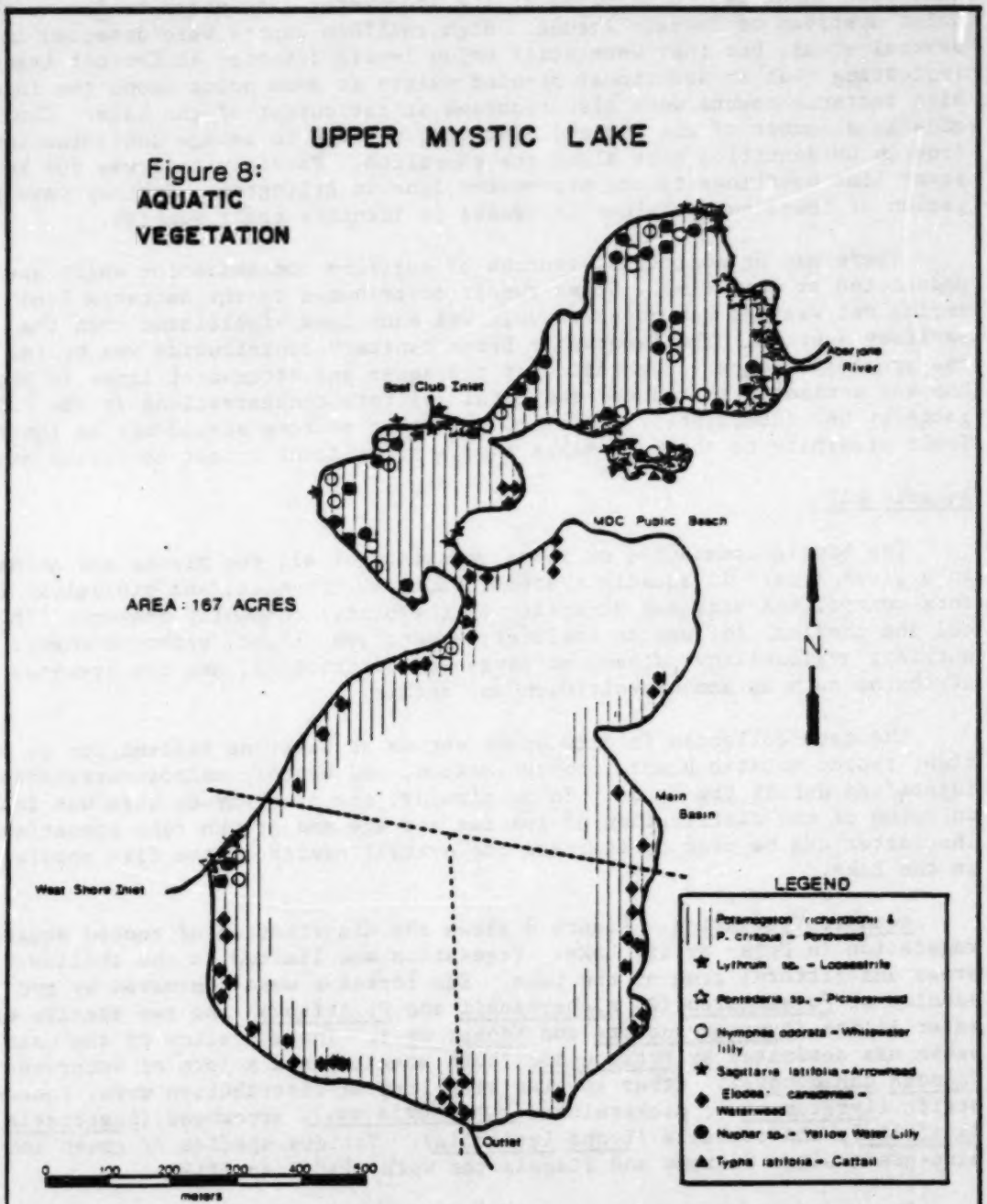
Aquatic Life

The biotic community, or biota, consists of all the plants and animals in a given area. In aquatic systems, chemical, physical and biological factors control the size and diversity of the biotic community present. Physical and chemical influences include: temperature, light, water movement, nutrient availability, dissolved oxygen concentrations, and the presence of toxins such as ammonia-nitrogen and metals.

The data collected in this study serves as baseline information on the fish, rooted aquatic plants, phytoplankton, and benthic macroinvertebrates identified during the study. In particular, the fish survey data was analyzed in terms of the distribution of species and age and growth rate comparisons. The latter can be used to indicate the overall health of the fish population in the Lake.

Aquatic Vegetation. Figure 8 shows the distribution of rooted aquatic vegetation in Upper Mystic Lake. Vegetation was limited to the shallow areas and littoral zone of the Lake. The forebays were dominated by two species of Potamogeton (P. richardsonii and P. crispus) and two species of water lilies (Nymphea odorata and Nuphar sp.). The shoreline of the main basin was dominated by Potamogeton (both species) and a form of waterweed (Elodea canadensis). Other species with limited distribution were: loosestrife (Lythrum sp.); pickerelweed (Pontederia sp.), arrowhead (Sagittaria latifolia); and cattails (Typha latifolia). Various species of green and blue-green algae diatoms and flagelattes were also identified.

The physical characteristics of the sediments, the water depth, and water chemistry influence the distribution of plants in the Lake. The forebays receive a heavy load of organics and silt from the Aberjona River causing turbid conditions in the Lake. This impedes light penetration which explains


UPPER MYSTIC LAKE
Figure 8:
AQUATIC
VEGETATION
Boat Club Inlet
MDC Public Beach
AREA: 167 ACRES
N.
Main
Basin
West Shore Inlet
Outlet
0
100
200
300
400
500
meters
LEGEND
Potamogeton richardsonii & P. crispus = Pondweed
Lythrum sp. = Loosestrife
Pontederia sp. = Pickerelweed
Nymphea odorata = Whitewater lilly
Sagittaria latifolia = Arrowhead
Elodea canadensis = Waterweed
Nuphar sp. = Yellow Water Lilly
Typha latifolia = Cattail
1981
Department of Environmental Quality Engineering

why floating water lilies dominate the forebays in mid-summer. Less turbidity in the main basin allows submerged plants such as pondweed to flourish.

The two forebays suffer from excessive aquatic vegetation, particularly the upper forebay. The mouths of the Aberjona, West Shore Inlet and Boat Club Inlet are also areas impacted by excessive vegetation. All these areas of extreme growth reflect not only the high ambient concentrations of phosphorus in the Lake, but also the points of input at the Lake inlets. The rooted vegetation in the main basin is not as severe as the forebays due to its depth, however, the entire shoreline of the main basin, including an area extending twenty feet from the outlet dam, harbors excessive rooted growth.

The rooted plants do have some value in that they provide a habitat and food source for some fish such as Bluegills and Carp. The plants also help to filter out nutrients, metals and solids from the water. The decomposition of such biomass, though, can have a detrimental effect on fish by consuming large quantities of dissolved oxygen in the decomposition process.

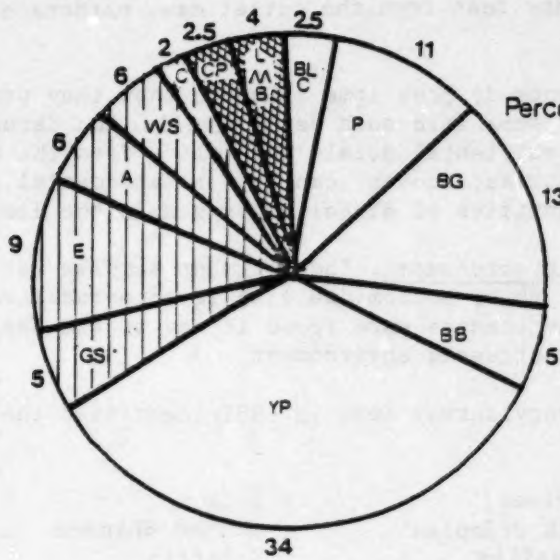
Benthic Macroinvertebrates. The sediment samples collected were analyzed to determine what type of bottom dwelling invertebrates were living in the Lake. No macroinvertebrates were found in any of the samples collected indicating an extremely stressed environment.

Fish. The fishery survey done in 1981 identified the following fish in the Lake:

Alewives	Eels
Black Crappies	Golden Shiners
Bluegills	Goldfish
Brown Bullheads	Large Mouth Bass
Carp	Yellow Perch
Chain Pickerel	White Suckers

Figure 9 shows the relative quantities of the various fish found. As can be seen, most of the fish in the Lake are classified as pan fish which are generally more tolerant of polluted conditions than game fish. The growth rate data collected indicated that the existing fish populations are relatively healthy. Local fishermen have, however, reported fish kills and an increase in flesh lesions and disease in 1982. These reports need to be further investigated. In terms of the water quality conditions required to support a game fishery, several major problems have been identified including dissolved oxygen distribution, high ammonia and metals concentrations and bacterial and viral contamination from sanitary discharges. While each of these conditions is important by itself, it should also be remembered that in combination they can create a stressed environment and make the organism more sensitive to a particular pollutant.

Figure 9: UPPER MYSTIC LAKE FISH POPULATION DISTRIBUTION*



KEY

Fish Type

Pan Fish | Forage Fish | Game Fish

Fish Species

LMB - Large Mouth Bass	GS - Golden Shiners
P - Pumpkin Fish	E - Eels
BG - Bluegills	A - Alewives
BB - Brown Bullheads	WS - White Suckers
YP - Yellow Perch	C - Carp
BLC - Black Crappies	CP - Chain Pickerel

* Population Distribution based on time-shock method

Data collected by Massachusetts Division of Fish and Wildlife, Acton, 1981.

5 POLLUTION SOURCES & CONTROLS

One of the primary objectives of this project was to characterize urban runoff pollution in the Watershed. To do this effectively, an investigation of other potential pollution sources in the Watershed was also necessary so that the contribution of urban runoff could be separated from other contaminants.

In this chapter urban runoff and some of the other potential sources will be briefly discussed and results of the evaluation of control options presented.

SOURCES AND CHARACTERISTICS OF URBAN RUNOFF POLLUTION

The types of runoff contaminants which end up in stormwater vary greatly, and determining their origin is often difficult. The contaminants found in stormwater can be traced to specific sources such as automobiles, fertilizers, soils, litter, the atmosphere, leaves, and other plant materials as seen in Table 1. Although these contaminants are regularly found in runoff, their quantity varies geographically due to factors such as land use, climate, and geology. One of the goals of this project was to identify the characteristics of local runoff.

Two stormwater sampling stations were established to measure runoff quality and quantity from small areas with one type of land use. The stations were located at Hemlock Road and at the Addison-Wesley parking lot in Reading. The Hemlock Road site (EOPA) drained a 50 acre residential area (85% residential, 15% open space) and the Addison-Wesley site drained an 18 acre office park. Table 13 compares pollutant concentrations found at the two sites. Runoff from the residential area is significantly higher in organic matter, as measured by volatile suspended solids and total kjeldahl nitrogen. Animal wastes, grass clippings, leaves and other debris are likely sources of this material.

Table 13: COMPARISON OF STORMWATER QUALITY

MEDIAN CONCENTRATION

	Hemlock Road	Addison-Wesley
Total Suspended Solids (mg/l)	62.5	3.0
Volatile Suspended Solids (mg/l)	41.0	8.3
Total Phosphorus (mg/l)	0.3	0.1
Total Kjeldahl Nitrogen (mg/l)	13.0	2.0
Nitrate - Nitrogen (mg/l)	2.9	1.2
Ammonia - Nitrogen (mg/l)	0.4	0.4

Residential runoff was also higher in phosphorus and nitrate-nitrogen, two major components of fertilizer. All these values are also well within the ranges found in runoff elsewhere in the country. Metals values recorded at the two sites were similar.

The rate at which pollutants are washed off of a land surface is dependent on a number of factors including land use, storm intensity, and pollutant characteristics. In first flush, pollutant concentrations in runoff are higher during the first part of a storm as they are effectively being flushed from the land surface. Data from several sampling stations was analyzed for this effect since it can be used to indicate if treatment of only the first portion of the runoff generated would effectively reduce the pollutant load. For most stations, first flush effects were observed for total suspended solids and phosphorus species. The concentrations of nitrogen compounds tended to remain constant throughout the storm. No first flushes were observed at the USGS station, probably due to the cancelling of the many stream loads.

In addition to the specific analysis done on stormwater, the stormwater and wet weather Aberjona River data collected were used to develop annual loads to the Lake. Table 12 showed the relative contribution of urban runoff to Lake loadings. As seen there, urban runoff contributed over 50% of the nitrate, biochemical oxygen demand, manganese and arsenic loads and between 20 and 50% of the suspended solids, phosphorus, ammonia, copper, iron, and lead loads; and as such is a significant source of pollution.

OTHER NONPOINT SOURCES

The non-point sources of pollution in the Watershed, excluding urban runoff, are mainly related to past and present industrial waste disposal practices in the Upper Watershed. One major area of concern is the D'Anolfo property, commonly referred to as the Industri-plex site, located just north of Route 95 in Woburn near the former site of Mishawum Lake. During preparation of the land for new industrial development, waste deposits from past industries

were uncovered including animal hides buried in the mid-1900's by glue manufacturers and waste deposits with high concentrations of arsenic, lead and chromium.

The severity of the problem was acknowledged by EPA when the site was ranked in the top ten on their list of hazardous waste sites in the country.

In order to regulate and financially assist states with the clean-up or containment of these sites, the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 was passed. Under the provisions of that law Stauffer Chemical is presently conducting a detailed study of the site and is committed to its share of clean-up. The Stauffer investigation includes an assessment of the location, composition and quantity of waste deposits on the site and their impact on ground and surface waters and will propose remedial actions. That study will be completed in 1983 and clean-up will follow.

Development of the site was eventually discontinued when the problem was recognized and in June of 1981 a perimeter fence was installed to secure access to the site. The site is of concern with regard to surface water contamination because the Aberjona flows through the site and groundwater is a major source of baseflow. Halls Brook storage area is also in close proximity to the study area.

As discussed in Chapter 4, high ammonia levels in the Aberjona and Upper Mystic Lake are a result of groundwater contamination at the Olin Chemical Company (formerly Stepan) site in Wilmington. High concentrations of ammonia, sulfate, chlorides, and dissolved solids have been detected in the drainage ditches which surround the plant now owned by Olin Chemical Company. Data on the ditches at the eastern border of the Olin site, collected under this study, supported these findings. Contaminated groundwater discharges to these ditches and then flows down to Halls Brook and the Aberjona River.

From sometime prior to 1965 until July 1971, wastes were discharged into unlined "acid pits" on the site. These wastes were untreated and contained contaminants such as those just mentioned. For the next year the wastes were treated before being discharged into the pits. In 1972, these pits were replaced with two polyvinal chloride lined lagoons. The effectiveness of the liners was lost when punctures occurred. This problem and the prior use of the unlined "acid pits" are believed to be the primary sources of the contaminants found in the groundwater. A study recently conducted for Olin Chemical showed that the ammonia plume in the groundwater is highest in the vicinity of the lagoons, with a secondary plume located near some storage tanks on their property. In this area, the source is believed to be faults in the sewer line.

DEQE is currently working with Olin Chemical on remedying the situation. During the summer of 1981 the liner in one lagoon was replaced with a thicker barrier designed with more safety features. The second liner should be replaced sometime within the next year. In addition, a closer examination of the sewer line will be conducted so that appropriate repairs can be made.

If these problems are solved and no further sources of contamination are detected, the quality of the ground and surface waters in this area should improve over time. There are currently no plans for groundwater treatment.

Another contributor of non-point source pollution is the Woburn landfill. Leachate from this area enters the Brook which borders its southern end. Previous reports have indicated that the high iron concentrations present in the Hall's Brook area were attributed to the landfill. Recent data collected in this area support this theory. Although the concentration of iron in the Brook south of the landfill shows evidence of some iron contamination, this is not the only area with this problem. Slightly upstream of the landfill, iron was also found in the drainage network along the B & M Railroad. Concentrations substantially greater than those observed near the landfill were detected. It is evident that the landfill is a contributor to the load of iron in this area but that there is also an additional source which has not been identified.

POINT SOURCES

In an effort to quantify and control the wastes being discharged from point sources, the National Pollutant Discharge Elimination System (NPDES) was established under Section 402 of the Federal Clean Water Act. To legally dispose of pollutants in navigable waters, the discharger must obtain an NPDES permit from EPA or an authorized state agency. These permits outline effluent limitations and monitoring requirements which the discharger must comply with.

Applications for 16 permits have been received for point discharges in the Upper Mystic Lake Watershed since the start of the program (see Table 14). Of these applications, only five permits were issued. All five issued permits have passed their expiration date; however, two have been terminated and two have connected to the MDC system since their time of application. The remaining permitted discharge consists of cooling water from J.H. Winn, Inc. in Winchester. This discharge is felt to be beneficial to the Aberjona River because the discharge water which originates from wells helps to diminish the low flow problems. Ten of the remaining 11 dischargers are connected to the MDC Sewer System which transports their wastes to the Deer Island Treatment Plant, eliminating the need for NPDES permits. The final NPDES applicant was Stepan Chemical Company. No permit was issued for their discharge which was labelled by EPA as a "special problem" due to their waste disposal practices at the site as discussed above.

Additional point source problems in the Watershed can be attributed to surcharging sewers, particularly in the Towns of Stoneham and Winchester. Nineteen combined manholes located in three areas of Stoneham cause sewer overflows into Sweetwater Brook. At these points, the stormwater and sewer lines are open to each other at manholes. If a blockage occurs in either line or if their capacities are exceeded, the sewage and stormwater mix. Sewage laden stormwater then travels to Sweetwater Brook. A study of the combined manholes has been completed, but funding for the alterations necessary is being delayed. Funding for the Stoneham sewer line studies included an investigation of the town's pumping station which does not have the capacity to

Table 14: POINT SOURCE DISCHARGE PERMITS

Discharge	Community	Federal Permit Number	Mass. Permit Number	Date Issued	Date Expired	Receiving Location
Raytheon Co. Spencer Lab	Burlington	MA0001431		4/21/75	1/1/76	Terminated
RCA Corp.-Aerospace Systems Division	Burlington	MA0001546				Deer Island STP
Montvale Enterprises	Stoneham	MA0020443				Deer Island STP
Sanborn Trucking Co.	Stoneham	MA0023671				Deer Island STP
Stoneham DPW	Stoneham	MA0102059	M-147	6/12/75	4/1/76	Deer Island STP
Compugraphic Corp.	Wilmington	MA0024171				Wilmington WTF
Stepan Chemical Co.	Wilmington	MA0005304	M-441			Special Problem
Swift Edible Oil Co.	Winchester	MA0020923				Deer Island STP
J.H. Winn, Inc.	Winchester	MA0001279	M-35	6/29/73	6/29/78	Aberjona River
A-1 Precious Metal Plating, Inc.	Woburn	MA0024490				Deer Island STP
Atlantic Gelatin	Woburn	MA0020401				Deer Island STP
Joseph P. Mahoney Co.	Woburn	MA0024139				Deer Island STP
Lipton Pet Foods, Inc.	Woburn	MA0023124				Deer Island STP
Systems Printed Circuit Corp.	Woburn	MA0021601	M-432	4/21/75	1/1/76	Terminated
Woburn	Woburn	MA0102008		10/31/75	6/7/77	Deer Island STP
Woburn Dump	Woburn	MA0023591				Woburn SD

Source: U. S. EPA, 1981.

adequately handle current flows. This study has not been completed at this time; and the funding for the manhole repairs is tied to completion of this investigation.

Winchester completed an infiltration/inflow study in 1978 which identified a number of problems in the sewer system, ten of which potentially surcharged to the Lake or its tributaries. Additional work has been completed since that time to further investigate those problems and evaluate corrective measures. The recently completed facilities plan presents the results of that investigation reducing the number of problem areas from ten to six. Table 15 lists the six problem areas and recommended remedial actions. Winchester has developed a ten year strategy using town funds to make the needed changes and repairs in the sewer system. If funding is available from DEQE's Construction Grants Program the work could be completed sooner.

Elevated bacteria and nutrient levels, and blue-tinted water were detected at the Boat Club Inlet on several occasions. Upstream of the Everett Avenue sampling station is the point of discharge for a section of Winchester's stormwater drainage system at Glen Road believed to be a possible source of this contamination. To investigate this, bacteria samples were collected at four points within the stormwater system during dry weather. The results of this survey indicated the presence of coliform bacteria at several points in the line but do not fully explain bacteria levels at the inlet since the Glen Road site, which is the stormwater discharge point to the inlet, had lower levels than the inlet itself. Further investigation of this problem is needed.

Additional sewer problems have been identified within the MDC system and excessive infiltration/inflow in Woburn is one suspected cause of these overflows. An infiltration/inflow study should be conducted in Woburn so that plans to alleviate these problems can be developed. High bacteria counts were also recorded at the outlet of the Lake during the sampling in the southern part of the Lake and of the stormwater outfalls along the Arlington shoreline.

Another stormwater outfall to the Lake was sampled after the presence of an orange discharge was reported by a nearby resident. This discharge located off Niles Lane in Winchester, had a high iron concentration explaining the orange precipitate. Further investigation is needed to determine the severity and source of this problem.

There are probably other undetected sources of pollution in the Upper Mystic Lake Watershed; however, knowledge of the sources discussed in this chapter has helped to explain some of the water quality traits observed.

CONTROL OPTIONS

Controlling surface water pollution in the Upper Mystic Lake Watershed is a difficult task. Methods include abating the pollution attributed to urban runoff and other known sources of pollution in the Watershed, as well as employing in-lake controls to alleviate problems resulting from contamination.

Table 15: AREAS WITH SURCHARGING SEWER PROBLEMS IN WINCHESTER

Area	Reason	Recommendation
Surcharging to the Boat Club Inlet		
- At intersection of Wildwood and Albmont Streets	- Inadequate sewer capacity on Cambridge Street	- Relief sewer on Wildwood to Wedgemere Avenue
Surcharging to Horn Pond Brook		
- Off Sylvester Avenue	- Inadequate sewer capacity	- Remove part of service area from this collection sewer (see below)
- Off Horn Pond Brook Road	- Sediment accumulation in inverted siphon	- Eliminate siphon with new connection to MDC sewer and remove this area from downstream collection sewer(as above)
Surcharging to Upper Mystic Lake		
- Between the two forebays of the lake (W6 on Figure 3-3)	- Inadequate capacity in the sewer and siphon	- Construct a relief sewer and new siphon inlet structure
- Off Cambridge Street (W5 on Figure 3-3)	- Inadequate capacity in the sewer	- Construct relief sewers. Eliminate excessive I/I
Surcharging to Shaker Glen Brook		
- Off Thornberry Road	- Wet weather flow exceeds pumping capacity	- Overhaul pumps and piping to increase pumping capacity. Eliminate excessive I/I

Source: Coffin & Richardson, 1982.

Although these categories will be discussed separately it is important to remember that an effective watershed management plan needs to consider both these areas. In-lake control measures can temporarily alleviate the symptoms of contamination, such as algae blooms and weed growth, but most cannot solve the problem until the sources have been controlled.

The Main Report evaluates various urban runoff controls in some detail including runoff volume reducers, erosion and sedimentation controls, pollutant source controls and within these categories the regulatory jurisdictions of local boards and commissions. While this detailed information will not be repeated here the basic conclusions will be presented.

Going back to Chapter 4, four major sources of pollution to the Upper Mystic Lake were identified. For the pollutants of concern (nitrogen, phosphorus, coliform, and metals), their sources are as follows:

Source	Pollutant
Urban Runoff	Phosphorus, Metals
Sanitary/Stormwater Connections	Phosphorus, Coliform, Metals
Baseflow	Nitrogen, Phosphorus, Metals
Internal Sediment Loads	Phosphorus, Metals.

Controlling these sources and the impacts they have on Upper Mystic Lake can be accomplished in two ways: (1) the source of the pollution can be controlled through watershed controls, or (2) the symptoms of the problem can be temporarily treated using in-lake controls. Source control is preferred as it has a more permanent impact, but for non-point sources is often difficult. The control evaluation of this project consider both of these types of control.

Watershed Controls

Urban Runoff. Controlling urban runoff pollutants in the Watershed will be extremely difficult due to their widespread distribution. The stormwater modeling done under this project did not identify any critical areas where the area contribution (lbs/acre) of urban runoff pollution was higher than other areas; therefore, pinpointing certain geographical areas where runoff controls would be most effective was not possible.

A major difficulty in terms of controlling urban runoff in this Watershed in the design of the stormwater collection systems. Stormwater is discharged at a large number of locations, over 150 in all, within each community instead of only a few points. The expense of installing and maintaining a treatment device at each outfall, or constructing interceptors to transport the runoff to one location for treatment, would be prohibitive. Similarly, the construction of new detention basins or other control areas may be difficult or costly to site within the highly developed Watershed.

In areas where development is still occurring or where existing drainages are being altered or repaired, erosion and sedimentation and volume reduction controls, should be required to prevent further water quality degredation. Conservation commissions and planning boards can require developers to minimize the size of the disturbed area and to use controls such as runoff diversion, slope stabilization, and sediment basins and traps. The selection of controls will vary for each construction site. Development drainage plans should minimize the net change in the quantity and rate of runoff from a site prior to the proposed development. Proper maintenance of catch basins through regular removal of collected residual can reduce loads of suspended materials including lead, organic matter, and phosphorus. The optimum cleaning frequency is site specific, but each community can identify areas where sediment deposition is greater and more frequent cleaning called for.

Source controls which reduce the amount of pollutants available to be collected by runoff, are probably the most practical control method in this Watershed. Operation and maintenance practices such as street sweeping and road maintenance can reduce the amount of particulate matter available to be washed off. As with catch basin cleaning, the optimum frequency for street sweeping varies, with the costs incurred weighing against water quality improvement. Street sweeping is not a particularly effective means of phosphorus control, but can remove up to 35% of the lead present on roadways. Again, towns can identify areas of particular concern, which for lead are generally the more heavily trafficed areas, and increase sweeping to the extend possible. Although street sweeping may not be the most efficient, it is probably more cost-efficient than most of the options available.

Educating the public on methods of pollution reduction can also be an effective means of source control. Brochures outlining guidelines for proper automobile maintenance, fertilization and pesticide use, and solid waste disposal, as well as the water quality benefits attained from reducing the pollutants coming from these sources, can be distributed to the public. Often people are unaware that some of their activities pollute the environment and that their activities can affect their downstream neighbors. Enforcing existing fines for littering or instituting new fines would also reduce pollution to some extent. Not only will this generate revenue, but it will also improve the appearance of the community. Often this added incentive is needed to bring about a noticeable response. While implementing source controls on an individual basis may seem to have an insignificant effect, the cumulative effect of widespread control can result in significant improvements in water quality.

Sanitary/Stormwater Connections. Contamination of stormwater runoff and subsequently surface waters by sanitary discharges is a major problem in the Watershed contributing large quantities of phosphorus, certain metals, and bacteria to Upper Mystic Lake. Funding for the separation of 19 combined manholes in Stoneham, the major contributor, will not be available until a study of the town's pumping station is completed.

Winchester has completed a facilities plan for the correction of several problems resulting in sewer surcharging, two of which discharge directly to the Lake through stormwater outfalls. They have also developed a ten year

strategy for completion of the corrective measures using town funds. If state funds are made available this work could be done much sooner.

Arlington is currently conducting an infiltration/inflow study which should identify problems in that system. The Arlington drainage to the Lake should be included in that effort in an effort to find the source of high coliform levels recorded at the Lake outlet. A plan for eliminating sewer surcharging to Horn Pond in Woburn needs to be developed. It has been suggested that excessive infiltration inflow to the sewer system in Woburn is a contributing factor. This should be investigated.

Baseflow. Baseflow, the water which supplies flow during dry weather (usually groundwater), was found to contribute unusually high amounts of nitrogen, phosphorus, and some metals. Normal background levels account for some of the baseflow load, but groundwater contamination is evident. High ammonia levels in the Aberjona River and Upper Mystic Lake are primarily due to groundwater contamination in Wilmington at the Olin Chemical site which discharges to drainage ditches on site and then flows down to Halls Brook and the Aberjona River. High iron concentrations have been attributed to leachate from the Woburn Landfill, but elevated concentrations have also been seen in the railroad drainage ditches above that site. Manganese levels were also high in these ditches. Further investigation is needed to try to locate the sources of the iron, manganese and phosphorus contamination found in the baseflow. Baseflow contributions are extremely difficult to control. The instream detention area discussed below could, however, reduce those contributions through settling and plant uptake.

In-Lake Controls

Again, the Main Report discusses a wide range of in-lake controls including aeration, biological treatment (introduction of predator organisms), chemical treatment to control vegetation or tie-up phosphorus, weed harvesting, in-lake detention areas, dredging, and sediment covering. All of these controls could be implemented in the Upper Mystic Lake, but many would be expensive, yield minimal results, and/or be harmful to aquatic organisms. It is also important to emphasize that many of these controls will have only limited effectiveness unless Watershed controls are in effect. The in-lake controls best suited to the problems of the Upper Mystic Lake are aeration to keep oxygen in the deep water during stratification, weed harvesting and shoreline sediment covering to control noted vegetation, and in-lake detention.

Aeration. There are two methods of aeration. Hypolimnetic aeration puts oxygen into hypolemnetic waters withoug disrupting thermal stratification. Artificial destratification or circulation also aerates hypolimnetic waters but causes the entire water column to mix. Both methods put oxygen in the water column and inhibit phosphorus and metal release from the sediments, but artificial destratification will eliminate the possibility of establishing a cold water fishery. Mixing the entire water column, as is done during artificial destratification, makes the water temperature uniform. This leaves no cold bottom waters which are needed to support cold water game fish such

as trout. While both methods are expensive to establish initial capital costs for hypolimnetic aeration are considerably greater. MDC has the equipment needed for artificial destratification. The equipment is currently being used for a project being conducted on the Lower Mystic Lake, but could possibly be transferred at a later date to the Upper Lake. This would lower the initial capital investment costs. Operation and maintenance cost would reflect the frequency at which the aerators are used, since repeated aeration is required to keep oxygen in the bottom waters.

Control of Rooted Vegetation. The mechanical or manual removal of nuisance vegetation from a lake is known as harvesting. This practice would need to be repeated at least once each year, but after numerous cuttings weed growth tends to be reduced. One disadvantage is that the phosphorus normally taken up by the weeds may encourage algal blooms, but controlling phosphorus loadings through Watershed controls could decrease the chances of this problem occurring. Also, the use of fiberglass netting to cover shoreline sediments inhibiting rooted aquatic plant growth, although expensive, may be efficient when used in small areas. Lakefront residents could use netting to eliminate the weed problems adjacent to their property.

In-Lake Detention. Another option is the use of retention/sedimentation basins to remove pollutants. In effect, the upper forebay of the Lake is presently acting as a sedimentation basin and could be more effectively used if a baffle system was installed to further increase retention time and vegetation was harvested to prevent nutrients and oxygen consuming materials from entering the rest of the Lake. Occasional sediment removal would also be needed. This option does, however, have a major drawback. By utilizing the upper forebay for treatment purpose other uses would be restricted and aquatic vegetation would become more dense. Since this may not be desirable another possibility it to investigate the use of the Aberjona just upstream from the Lake for a similar purpose. This option needs to be further investigated.

6. SUMMARY

This project has identified a number of major water quality problems in the Upper Mystic Lake Watershed, particularly the Lake itself, including:

(1) public health concerns due to sewage contamination,

(2) nuisance aquatic vegetation resulting from high phosphorus levels,

(3) maintenance and improvement of game fisheries threatened by high ammonia and metals levels, and

(4) suitability of fish for human consumption.

The Watershed is recognized as an important water resource and it is obvious from this study that a concerted effort is needed to improve water quality conditions in order to attain water quality goals. This effort must recognize that water knows no town lines and that upstream activities are affecting downstream neighbors. As in many urban watersheds, this will not be an easy task, but certainly is not an insurmountable one.

This project has identified various sources of pollution which need to be controlled, some of which still need to be further investigated. The control of sanitary sewer overflows will result in a significant improvement in water quality. Funding for such projects is limited, however, and local support is crucial. Urban runoff is a major source of a number of pollutants of concern. Unfortunately, no easy solution for controlling urban runoff exists. Controlling the sources of contaminants before they are picked up by runoff is the most feasible approach, but will require a great deal of diligence on the part of local officials and residents. The in-lake control options discussed above deserve serious consideration, but it is important to remember that they often only treat the symptoms and will have to be used repeatedly unless the sources of pollution are also controlled.

The results of this study can be used as a guide for action by local and state officials and Watershed residents. The following is a summary of next steps which should be taken with the ultimate goal of improving water quality in the Upper Mystic Lake Watershed.

Controlling Sources of Pollution

- Secure funding for combined manhole separation in Stoneham and Winchester's facilities plan for relieving surcharging sewer problems.
- Investigate the additional sources of bacterial contamination identified in Woburn, Arlington and Winchester.
- Options for preventing ammonia laden water from flowing into Halls Brook from the Olin Chemical property in Wilmington should be given serious consideration.
- Organize community support to reduce urban runoff pollution to the extent possible through source controls.
- Investigate possible sources of the high levels of certain pollutants found in Aberjona River baseflow and the iron discharge from the Niles Lane stormwater outfall.
- Determine the importance of sediment release as a source of phosphorus and metals.

Defining Water Quality Goals

- Additional consideration should be given to the desire and feasibility of establishing a cold water fishery in Upper Mystic Lake, as this will, to some extent, define control needs.

Further Investigation of Water Quality Impacts

- The toxicity of metals and ammonia levels found in Upper Mystic Lake should be further investigated and the cause of fish kills and disease reported in the future determined.
- Fish should be analyzed for potentially toxic organics to better determine suitability for human consumption and guidelines for metal levels in fish flesh should be developed.

Evaluation of In-Lake Controls

- Based on results of additional investigation of the importance of sediment release and on decisions regarding the desire and feasibility of establishing a cold water fishery, the two aeration options should be considered.
- The feasibility of developing an instream retention area in the Aberjona should be evaluated.

- As a remedial action weed harvesting of the forebays and main basin shoreline should be considered.

Additionally, one crucial issue remaining is possible sources of funding for the various needs identified. As discussed in Chapter 1, the purpose of the Nationwide Urban Runoff Program was to make recommendations to Congress concerning federal funding for stormwater projects. The national analysis should be completed soon and recommendations are forthcoming. However, even if the prognosis is favorable, funding will most likely not be made available in the near future due to budget limitations. Consequently, the recommendations of this report were developed assuming that large capital expenditures, such as would be required to construct interceptor stormwater lines, were not feasible. Combined sewer projects are currently eligible for funding under the states construction grants program but monies are limited and the issue is one of establishing priorities. Communities can of course fund projects without federal or state aid but are also faced with budget problems.

Funds available under the Federal Clean Lakes Program are presently extremely limited and only allocated to ongoing projects. More funds may be made available in the future, but that cannot be counted on. In Massachusetts, legislation was enacted in December of 1981 establishing a Massachusetts Clean Lakes Program and providing as much as $3 million a year from an existing state bond. Regulations for that program are currently undergoing public review and DEQE will begin accepting applications sometime early next year.

ABBREVIATIONS

CDM	Camp Dresser & McKee, Inc.
EDP	Environmental Design and Planning, Inc.
MAPC	Metropolitan Area Planning Council
Mass. DEQE	Massachusetts Department of Environmental Quality Engineering
DWPC	DEQE Division of Water Pollution Control
Mass. MDC	Massachusetts Metropolitan District Commission
Mass. WRC	Massachusetts Water Resources Commission
MRWA	Mystic River Watershed Association, Inc.
U.S. EPA	United States Environmental Protection Agency
U.S. FDA	United States Food and Drug Administration
U.S.G.S.	United States Geological Survey

BIBLIOGRAPHY

Camp Dresser & McKee, Inc., 1967. Report on the Aberjona River. Prepared for the Aberjona River Commission.

___, Resource Analysis, 1980a. Upper Mystic Lake NURP Case Study - Precipitation Analysis. Prepared for the Mass. Department of Environmental Quality Engineering.

___, Resource Analysis, 1980b. Aberjona River Basin Water Quality Summary. Prepared for the Mass. Department of Environmental Quality Engineering.

___, Resource Analysis, 1981a. Mystic River Comprehensive Hydrology Study: Phase II Report, Draft. Prepared for the Metropolitan District Commission.

___, 1981b. Coliform Correlation Analysis Using Existing Data: Mystic NURP. Prepared for the Mass. Department of Environmental Quality Engineering.

___, 1982. Upper Mystic Lake Nationwide Urban Runoff Program Case Study.

Cassidy, R.A., 1971a. The Upper Mystic Lake: History, Recreational Use, Ecology. Tufts University.

Chute, N.E., 1959. Glacial Geology of the Mystic Lakes - Fresh Pond Area - Massachusetts. U.S. Geological Survey Bulletin 1061-F.

Coffin & Richardson, 1982. The Town of Winchester Facilities Plan, Boston, Mass.

DeFeo, F.L., 1971. The Establishment and Operation of the Aberjona River Commission. Tufts University Thesis.

Geotechnical Engineers, Inc., 1978. Report on Groundwater and Surface Water Study, Stepan Chemical Company, Wilmington, Massachusetts. Sponsored by the Massachusetts Division of Water Pollution Control.

Kaye, C.A., 1976. The geology and early history of the Boston area of Massachusetts, a bicentennial approach. Geological Survey Bulletin 1476.

Massachusetts Department of Environmental Quality Engineering, Division of Water Pollution Control, 1975. Upper Mystic Lake Water Quality Study: April 1974 - April 1975. Westborough, Mass.

____, Division of Water Pollution Control, 1976. Mystic River 1975 Waste Discharge Survey. Publication No. S673-37-100-2-76-CR, Westborough, Mass.

____, Division of Water Pollution Control 1977. Metropolitan Area Planning Council Areawide Wastewater Management Study Wet Weather Survey Data. Publication No. 10325-28-50-3-78-CR, Westborough, Mass.

____, Division of Water Pollution Control, 1981c. The Mystic River 1978 Water Quality Data, Westborough, Massachusetts.

____, DWPC, 1982a. NPDES files.

____, DWPC, 1982d. The Mystic River: Water Quality Data 1979, 1980 & 1981. Westborough, Massachusetts.

Massachusetts Metropolitan District Commission, Environmental Quality, 1977. Mystic River Watershed 1975-1976 Water Quality Survey. Boston, Mass.

____, Environmental Quality Division, 1978. Mystic River Watershed Water Quality Survey 1977. Boston, Mass.

____, Environmental Quality Division, 1979a. Mystic River Watershed Water Quality Survey 1978. Publication No. 11243-49-75-3-79-CR, Boston, Mass.

____, Environmental Quality Division, 1980. 1979 Mystic River Watershed Water Quality Survey. Publication No. 12011-71-50-7-80-CR, Boston, Mass.

____, Environmental Quality Division, 1981. Mystic River Watershed Water Quality Survey 1980. Publication No. 12446-84-50-6-81-CR, Boston, Mass.

____, Division of Water Pollution Control, 1974a. Mystic River 1967 Water Quality Survey Data. Westborough, Mass.

Massachusetts Water Resources Commission, Division of Water Pollution Control, 1974b. Mystic River 1973 Water Quality Survey Data Part a. Publication No. 6992-60-166-11-73-CR, Westborough, Mass.

____, Division of Water Pollution Control, 1975. Mystic River 1973 Water Quality Analysis, Part c. Westborough, Mass.

Massachusetts Water Resources Commission, Division of Water Pollution Control, 1978. Massachusetts Water Quality Standards.

Metropolitan Area Planning Council, 1977a. Mystic River Basin Preliminary Report. MAPC Water Quality Project. Boston, Mass.

Middlesex Canal Association, Inc., 1971. Guide to the Middlesex Canal 1793 - 1853. Billerica, Mass.

Resource Analysis, Inc., 1978. Mystic River Basin Comprehensive Hydrology Study: Phase I Report. Prepared for the Metropolitan District Commission.

Skehan, J.W., 1976. Puddingstone, Drumlins, and Ancient Volcanoes: A Geologic Field Guide Along Historic Trails of Boston. Boston 200 and Boston College Bicentennial Celebration.

Tufts University, Department of Urban and Environmental Policy, 1980. Hazardous Wastes in Woburn. Medford, Mass.

U.S. Environmental Protection Agency, 1976. Quality Criteria for Water. Washington, D.C., U.S. Government Printing Office.

____, 1980a. Water Quality criteria documents; availability. In: Federal Register, Part V, Vol. 45 No. 231.

____, 1981. P.C.S. Quick Look Report. Boston, Mass.

U.S. Geological Survey, 1944. Surficial Geologic Map of the Mystic Lakes - Fresh Pond Buried Valley Area between Wilmington and Cambridge, Massachusetts. Washington, D.C.

____, 1973. Water Resources Data for Massachusetts, New Hampshire, Rhode Island, Vermont.

____, 1980c. Water Resources Data for Massachusetts and Rhode Island. Water-Data MA-RI-80-1 .

____, 1980d. Hydrologic Data of the Coastal Drainage Basins of Northeastern Massachusetts, From Castle Neck River, Ipswich, to Mystic River, Boston. Massachusetts Hydrologic-Data Report No. 21.

____, 1980e. Hydrology and Water Resources of the Coastal Drainage Basins of Northeastern Massachusetts, from Castle Neck River, Ipswich, to Mystic River, River, Boston. (D.F. Delaney and F.B. Gay). Atlas HA-589.

GLOSSARY

ABBREVIATIONS	
cfs - cubic feet per second	°C - degrees Centigrade
mgd - million gallons per day	°F - degrees Fahrenheit
mg/l - milligrams per liter	ppm - parts per million
ug/l - micrograms per liter	EOP - end-of-pipe
mg/kg - milligrams per kilogram	IS - instream

Acute Toxicity - any poisonous effect produced by a single short-term exposure that results in severe biological harm or death.

Aeration - the entry of oxygen into water.

Aerobic - the presence of oxygen.

Algae - simple rootless plants that grow in water bodies.

Anaerobic - the absence of oxygen (also anoxic).

Anoxic zone - an area where no oxygen is present (also anaerobic).

Aquifer - an underground bed or layer of earth, gravel or porous stone that contains water.

Bacteria - single cell microorganisms that lack chlorophyll. Some cause diseases, others aid in pollution control by breaking down organic matter in water.

Bathymetric map - a map showing the depth from the water surface to the lake bottom.

Benthic macroinvertebrates - bottom-dwelling invertebrates that are large enough to be retained by a no. 30 U.S. Series sieve.

Bioaccumulation - the buildup of a contaminant in organisms as you move up the food chain.

Bioassay - a test to determine whether certain water quality conditions are toxic to a certain organism.

Biochemical oxygen demand (BOD) - the dissolved oxygen required to decompose organic matter in water.

Biodegredation - the decomposition of organic matter.

Biota - the plant and animal life of a region.

Chronic toxicity - any poisonous effect produced after long-term exposure to a contaminant that results in severe biological harm or death.

Deposition - the settling of solids to the bottom of the lake or stream.

Die-off-rate - mortality of a group of organisms which, assuming exponential decay, is the slope of a semilogarithmic plot of number over time.

Drawdown - lowering the water level of a lake.

Eutrophic - the state of a lake in which nutrient enrichment causes a rapid increase in productivity, often resulting in nuisance algal blooms, low transparency, extensive aquatic plant growth and loss of dissolved oxygen.

Epilimnion - the upper layer of water in a stratified lake located above the metalimnion.

Evapotranspiration - the total of the water lost to the atmosphere through surface water evaporation and plant transpiration.

Fecal coliform - the portion of the total coliform bacteria group which is contributed through the wastes of warm blooded animals, and are often used as an indicator of sewage contamination in waters.

Gneiss - a color banded metamorphic rock.

Granite - a common, coarse grained, light colored hard igneous rock.

Groundwater - the subsurface water which is located in soil and rock formations that are fully saturated.

Hydrology - the science dealing with the properties, distribution and circulation of water on the surface of the land, underground and in the atmosphere.

Hypolimnion - the bottom layer of water found in a stratified lake below the metalimnion.

Igneous rock - rock formed by volcanic action or great heat.

Infiltration - the action of water moving through small openings in the earth as it seeps into the ground.

Invertebrates - animals without backbones, such as insects and crustaceans.

Limiting nutrient - the nutrient required for plant growth, either phosphorus, nitrogen, or carbon, which is present at the lowest concentrations relative to plant growth needs.

Limnology - the study of the physical, chemical, and biological aspects of fresh water.

Littoral zone - the zone along the shoreline of a water body in which rooted plants can grow.

Macrophytes - large aquatic plants such as water lilies, pond weed, etc.

Metalimnion - the layer in a thermally stratified body of water, between the epilimnion and hypolimnion.

Metamorphic rock - rock which has been changed in form by heat or pressure.

Nonpoint source - a source of pollution that cannot be traced to one particular spot. An example is urban runoff.

Nutrient - a substance or ingredient which nourishes aquatic life.

Oligotrophic lake - a deep clear lake with low nutrient supplies containing little organic matter and high dissolved oxygen levels.

Organics - chemical compounds containing carbon atoms.

Outfall - the pipe at the end of a stormwater collection system (or treatment plant) which discharges to a water body.

Overland flow - water which runs off the land surface into a receiving water without entering a collection system.

Oxidation - the combination of a substance with oxygen, or, the removal of electrons (negatively charged particles) from an atom.

Pathogens - organisms, usually bacteria or viruses, capable of causing disease.

pH - a measure of the acidity or alkalinity of a material, liquid or solid. pH is represented on a scale of 0 to 14 with 7 being a neutral state, 0 most acid and 14 most alkaline.

Photosynthesis - a chemical process occurring in plants whereby carbon dioxide and water are synthesized into carbohydrates.

Phytoplankton - microscopic plants found in lakes and rivers.

B415
10

Plankton - microscopic plants or animals found in lakes and rivers.

Point source - a point from which pollutants are discharged (e.g. a pipe).

Productivity - the total quantity of organic material produced by organisms within a given period.

Retention time - the amount of time that water is retained or held in a lake before it is flushed out.

Sediment - the solid material that settles to the bottom of a river or lake.

Swale - a hollow or depression.

Thermal stratification - a condition which develops in a lake where temperature differences within the water column cause the water to have different densities at different depths; thus three separate zones are formed - the epilimnion, metalimnion and hypolimnion.

Thermocline - the point of maximum rate of temperature decrease with depth.

Total coliform - a group of bacteria primarily coming from animals and soils, commonly used as indicators of sewage contamination.

Trophic - pertaining to the degree of nutrient enrichment of surface waters (see eutrophic).

Turbidity - a cloudy condition in water caused by particles which interfere with the passage of light.

Watershed - the area of land that drains into a river or lake.

Water column - the vertical profile of water in a lake from the surface to the sediments.

Water table - the level at which fluid pressure equals atmospheric pressure.

Zooplankton - microscopic plants or animals found in river systems.